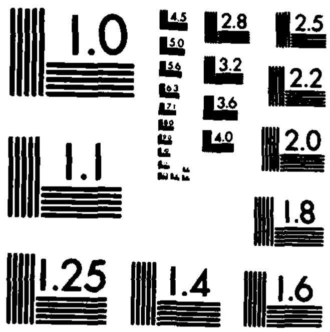
AD-A134 159 METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY APPENDIX G NON-STRUCTURAL STUDIES(U) CORPS OF ENGINEERS BALTIMORE MD BALTIMORE DISTRICT SEP 83 MWA-83-P-APP-G

UNCLASSIFIED F/G 13/2 NL



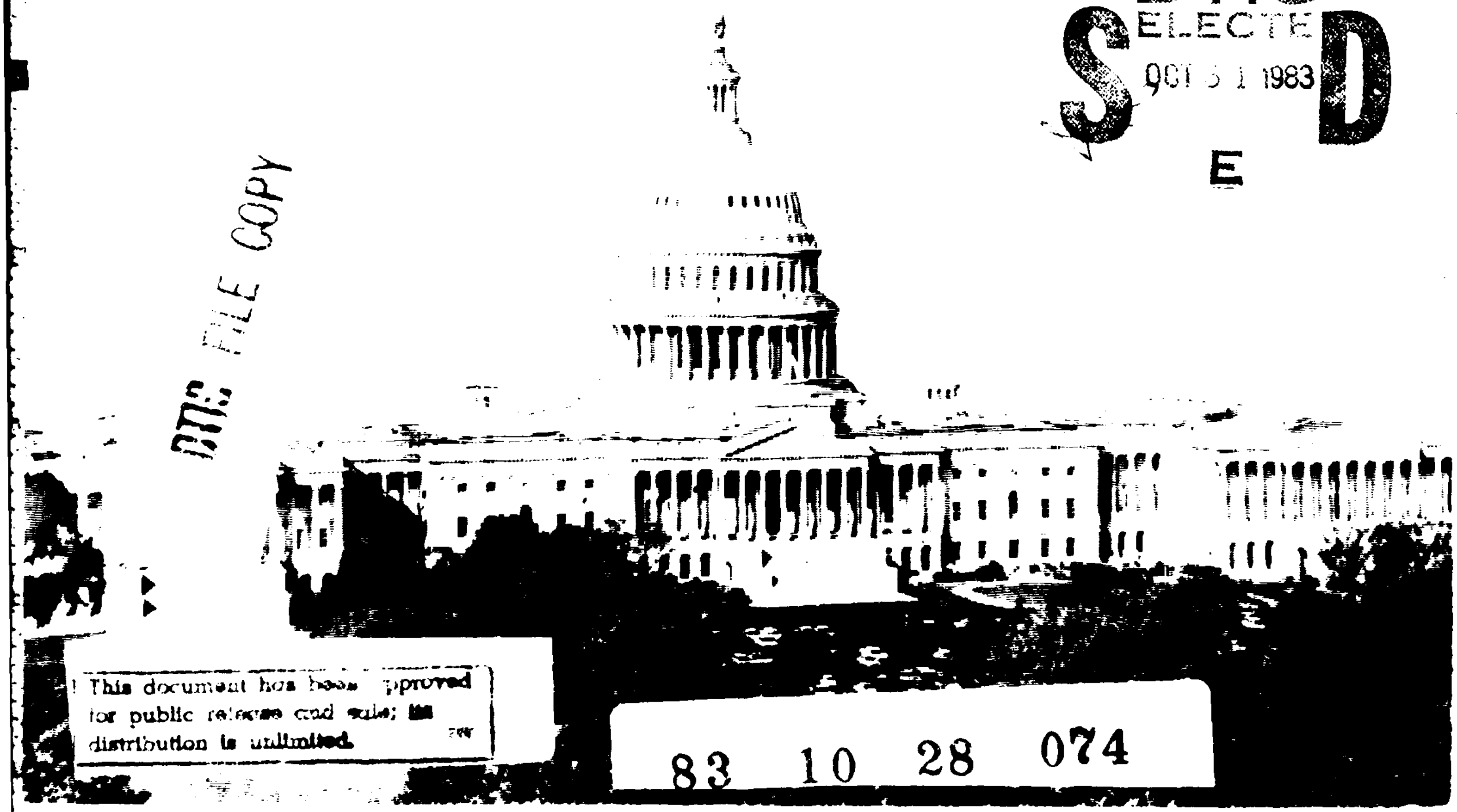
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Metropolitan Washington Area Water Supply Study

Appendix G Non-Structural Studies

Final/September 1983

A134159



83 10 28 074

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
MWA-83-P

2. GOVT ACCESSION NO.
A134159

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY, [redacted] Appendix [redacted] G

5. TYPE OF REPORT & PERIOD COVERED
Final

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Baltimore District
U.S. Army Corps of Engineers, ATTN: NABPL
P.O. Box 1715, Baltimore, Maryland 21203

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Baltimore District
U.S. Army Corps of Engineers, ATTN: NABPL
P.O. Box 1715, Baltimore, Maryland 21203

12. REPORT DATE
September 1983

13. NUMBER OF PAGES
~~3,000 pages, 1 plate~~

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

water resources planning; water demand; water supply; Potomac River; groundwater; reservoir; raw water interconnection; Low Flow Allocation Agreement; Bloomington Lake; Little Seneca Lake; wastewater reuse; Potomac Estuary Experimental Water Treatment Plant; PRISM/COE; water pricing; water conservation; demand reduction; Cooperative Operations on the Potomac; flowby;

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In response to the Water Resources Development Act of 1974, the Baltimore District of the U.S. Army Corps of Engineers conducted a comprehensive water supply analysis of the Metropolitan Washington Area (MWA). Severe water supply shortages had been forecast for the MWA and the study was undertaken to identify and evaluate alternative methods of alleviating future deficits. Initiated in 1976, the study was conducted in two phases over a 7-year period. The first, or early action phase, examined the most immediate water supply problems and proposed solutions that could be implemented locally. The second or long

19. KEY WORDS (continued)

water shortage; reregulation; finished water interconnection; Occoquan Reservoir; Patuxent Reservoir; Potomac Estuary; Water Supply Coordination Agreement; Verona Lake

20. ABSTRACT (continued)

range phase included an analysis of the full spectrum of structural and nonstructural water supply alternatives. In addition to such traditional water supply alternatives as upstream reservoir storage, groundwater and conservation, the study also considered such innovative measures as wastewater reuse, raw and finished water interconnections between the major suppliers, the use of the upper Potomac Estuary, reregulation and water pricing. A key tool in the study was the development and use of a basin-specific model that was used to simulate the operation of all the MWA water supply systems and sources under various drought scenarios. As the study progressed, local interests used the technical findings of the Corps' study to make great strides toward a regional solution to their water supply problems. The Corps' study concluded that with the implementation of a series of regional cooperative management agreements, contracts, selected conservation measures, and the construction of one local storage project to be shared by all, severe water supply shortages could effectively be eliminated for the next 50 years. The Final Report of the study is comprised of eleven volumes which provide documentation of both the study process and the results of all the technical analyses conducted as part of the study.

METROPOLITAN WASHINGTON AREA
WATER SUPPLY STUDY

APPENDIX G
NON-STRUCTURAL STUDIES

Department of the Army
Baltimore District, Corps of Engineers
Baltimore, Maryland

September 1983

REPORT ORGANIZATION*

METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY

Appendix Letter	Appendix Title	Annex Number	Annex Title
	Main Report		
A	Background Information & Problem Identification		
B	Plan Formulation, Assessment, and Evaluation	B-I	Water Supply Coordination Agreement
		B-II	Little Seneca Lake Cost Sharing Agreement
		B-III	Savage Reservoir Operation and Maintenance Cost Sharing Agreement
C	Public Involvement	C-I	Metropolitan Washington Regional Water Supply Task Force
		C-II	Public Involvement Activities - Initial Study Phase
		C-III	Public Opinion Survey
		C-IV	Public Involvement Activities - Early Action Planning Phase
		C-V	Sample Water Forum Note
		C-VI	Public Involvement Activities - Long-Range Planning Phase
		C-VII	Citizens Task Force Resolutions
		C-VIII	Background Correspondence
		C-IX	Coordination with National Academy of Sciences - National Academy of Engineering
		C-X	Comments and Responses Concerning Draft Report
D	Supplies, Demands, and Deficits	D-I	Water Demand Growth Indicators by Service Areas
		D-II	Service Area Water Demand & Unit Use by Category (1976)
		D-III	Projected Baseline Water Demands (1980-2030)
		D-IV	Potomac River Low Flow Allocation Agreement
		D-V	Potomac River Environmental Flowby, Executive Summary
		D-VI	PRISM/COE Output, Long-Range Phase
E	Raw and Finished Water Interconnections and Reregulation	E-I	Special Investigation, Occoquan Interconnection Comparison
F	Structural Alternatives	F-I	Digital Simulation of Groundwater Flow in Part of Southern Maryland
G	Non-Structural Studies	G-I	Metropolitan Washington Water Supply Emergency Agreement
		G-II	The Role of Pricing in Water Supply Planning for the Metropolitan Washington Area
		G-III	Examination of Water Quality and Potability
H	Bloomington Lake Reformulation Study	H-I	Background Information
		H-II	Water Quality Investigations
		H-III	PRISM Development and Application
		H-IV	Flood Control Analysis
		H-V	US Geological Survey Flow Loss and Travel Time Studies
		H-VI	Environmental, Social, Cultural, and Recreational Resources
		H-VII	Design Details and Cost Estimates
		H-VIII	Drawdown Frequency and Yield Dependability Analyses
		H-IX	Bloomington Future Water Supply Storage Contract
		H-X	Novation Agreement
I	Outlying Service Areas		

*The Final Report for the Metropolitan Washington Area Water Supply Study consists of a Main Report, nine supporting appendices, and various annexes as outlined above. The Main Report provides an overall summary of the seven-year investigation as well as the findings, conclusions, and recommendations of the District Engineer. The appendices document the technical investigations and analyses which are summarized in the Main Report. The annexes provide detailed data or complete reports about individual topics contained in the respective appendices.

METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY

APPENDIX G - NON-STRUCTURAL STUDIES

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (Cont'd)

LIST OF TABLE (Cont'd)

LIST OF TABLES (Cont'd)

ANNEXES

APPENDIX G

NON-STRUCTURAL STUDIES

INTRODUCTION

At least two events may have contributed to the decision by Congress in 1974 to author legislation calling for the Corps of Engineers to conduct a water supply study for the Metropolitan Washington Area (MWA). The National Capital Area, as well as the rest of the northeast, had recently recovered from a period of severely depressed water supplies and water shortages. This climatic occurrence may have been reason enough to warrant the study. However, the tremendous growth in the metropolitan region during the 1960's had continued into the early 1970's and there was ample reason to believe this trend would continue. With a scenario of potentially severe water shortages confronting the region, Congress authorized not only a study of water needs, but also an examination of alternatives to satisfy these needs.

The alternatives examined durng the seven years of study were of two general categories. Either they were of a nature requiring structural implementation or they were non-structural in nature and required implementation more from a political or personal perspective than from a project construction viewpoint. It is the purpose of this Non-Structural Studies Appendix to document the analysis and findings of the specific non-structural alternatives examined durng the MWA Water Supply Study. (Study documentation of those alternatives considered to be structural in nature is found in Appendix F - Structural Alternatives.)

This appendix presents information on those alternatives specifically mentioned in the authorizing legislation - wastewater reuse, water pricing policies, and conservation and demand reduction. In addition, one section of this appendix presents results of a water quality study conducted by the U.S. Environmental Protection Agency. While water quality is not, in the strictest sense, a supply augmentation or demand management measure, a broader perspective allows water quality to be included. This is so because (1) water quality impacts on the feasibility and acceptance of all alternatives; (2) the selection of a water quality level is itself a choice among alternatives; and (3) the selection or achievement of a certain water quality level may be translated into costlier construction and operation of projects. This, then, may lead to a more favorable view, and possible acceptance of, the nonstructural alternatives.

This appendix, then, is organized into four major sections addressing wastewater reclamation, water pricing, water conservation, and water quality. Within each of these sections will be found a description of the alternative, a discussion of the general methodology and fndings, and a brief explanation as to how the alternative was addressed in the formulation of plans. The annexes following the water quality presentation contain the technical reports on water pricing and water quality. A non-technical document is the Metropolitan Washington Water Supply Emergency Agreement included as Annex G-1.

WASTEWATER RECLAMATION

INTRODUCTION

The primary purposes of the long-range phase are twofold: (1) to develop water supply plans, designed to meet the needs of those portions of the MWA not treated in the 1979 Draft Progress Report; and (2) on a broader scale which encompasses the entire MWA, to assess the feasibility of a wider range of alternatives cited in the authorizing legislation which represent less certain yet potential means of providing additional water. One of the potential means explored was wastewater reclamation which is the subject of this section.

It should be noted that the level of detail adopted for the long-range phase of the study and hence the analysis of wastewater reclamation was less than survey scope. The results of the analysis will permit a comparison of preliminary costs, environmental impacts, and public acceptability of the alternatives considered. The data used in the analysis are based on the best available information which are subject to change due to advances in technology, changes in regulatory legislation, and changing public opinions and attitudes. The above qualifications are particularly appropriate to the wastewater reclamation analyses as the technological and social acceptability aspects of this sometimes controversial measure have undergone many changes over the last two decades. Nonetheless, the objective of the wastewater reclamation analysis was to evaluate the potential of this measure and develop cost, impact and assessment information such that reuse could be compared with the other long-range measures that were considered.

LAND APPLICATION

SCOPE AND PURPOSE OF INVESTIGATION

Land application is the treatment of wastewater involving utilization of plants, the soil surface, and the soil matrix to remove certain wastewater constituents. Traditionally, this mechanism has been used as a means to treat wastewater; however for this study this method was also examined as to its feasibility in reclaiming water for supply purposes. Included within this report are: a brief history of the land application process; descriptions of the requirements for mode of application, application rate and application season; an explanation of the approaches of application; relevant description of any necessary components pertaining to the Washington area; preliminary cost analysis; and conclusions regarding the feasibility of such a system in the Washington, D.C. area. The purpose of the study was only to examine the feasibility of land application for water supply and was not intended to identify specific site locations.

HISTORY OF LAND APPLICATION

Land treatment was used as early as the 1500's, however the practice has not been widespread over its history. Records cite land treatment systems or "sewage farming" as far back as 1531 in Bunzlau, Germany. By the 1870's, land treatment was being utilized in the United States. Although the number of systems has increased in recent years, only a small percentage of the total population is being served. The increase may be due in part to the enactment of PL 92-500. From this law and its amendments, the Environmental Protection Agency (EPA) administrator is directed to encourage waste treatment management that results in facilities for:

1. the recycling of po ;ntial pollutants via the production of agriculture, silviculture, and aquaculture projects,

2. the reclamation of wastewater, and

3. the elimination of discharge pollutants.

As an extra incentive, monetary benefits may be obtained if land treatment facilities are constructed. Also, there are savings in life-cycle costs of these systems versus conventional advanced wastewater treatment (AWT) facilities. These savings could be further augmented by reduction in energy costs. Because of these incentives, an investigation of land application was desirable during the early stages of the study.

LAND APPLICATION APPROACHES

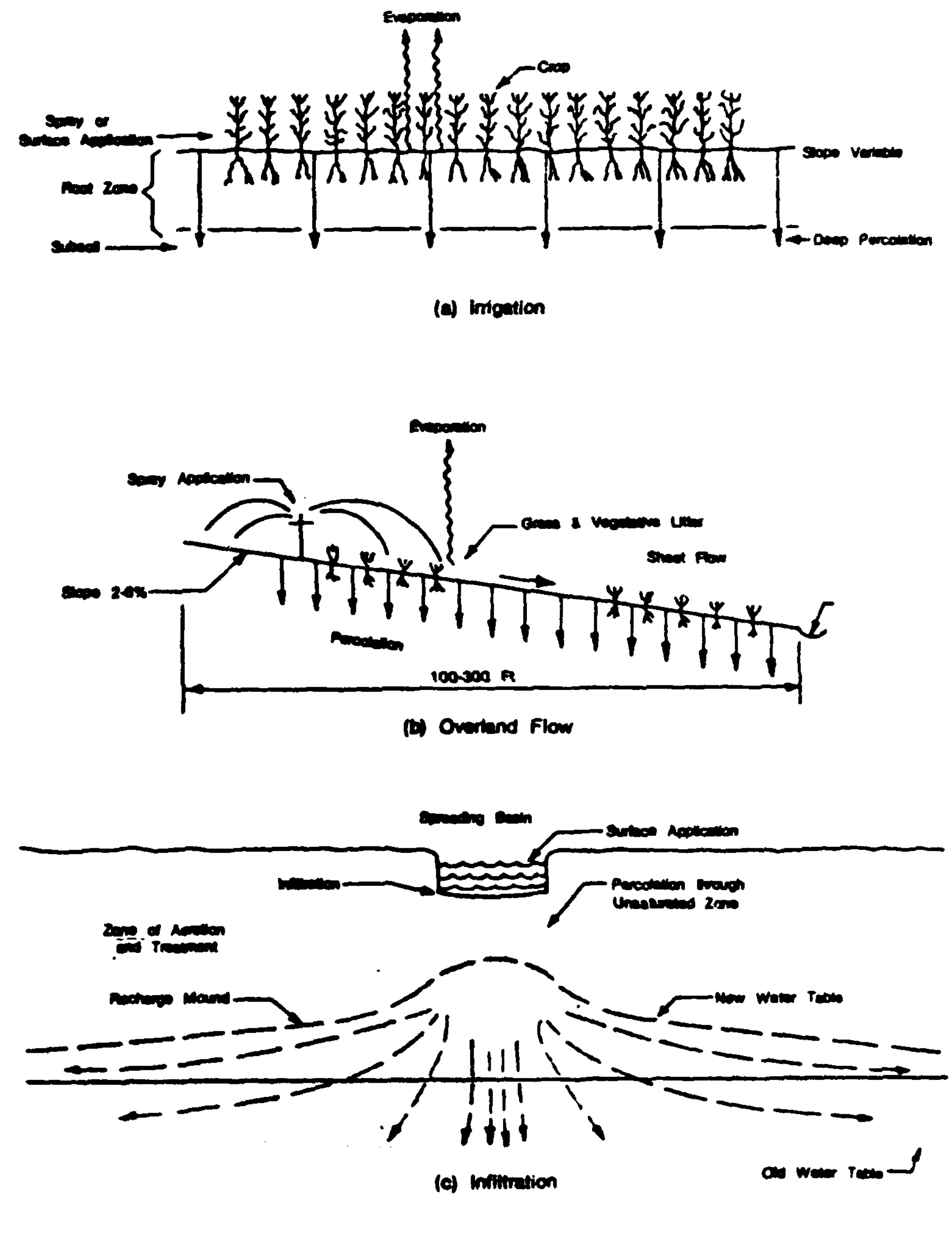
Three major land application approaches are available to renovate wastewater: crop or forest irrigation, overland flow, and rapid infiltration. Figure G-1 illustrates that for each of these techniques, certain slope, biotic, and application conditions are required. Table G-1 provides a brief comparison of design features and Table G-2 compares necessary site characteristics for the various application approaches. The following sections explain and summarize these approaches, highlighting the important design features listed in the tables.

Irrigation

Irrigation is the controlled discharge of effluent onto the land by spraying or surface spreading to support plant growth. Once applied, the wastewater is "lost" to plant uptake, to the air via evapotransporation, and to groundwater via percolation. Several physical factors govern the effectiveness of this method. These include the depth and permeability of soil, depth to the groundwater table, topographic and geologic conditions, land required, and vegetative cover. As seen in Table G-1, the last physical factor is a requirement for the irrigation process. Discussions of these factors follow.

FIGURE G-1

LAND APPLICATION APPROACHES



(a) Irrigation

(b) Overland Flow

(c) Infiltration

SOURCE: EPA Land Treatment of Municipal Wastewater

TABLE G-1

COMPARISON OF DESIGN FEATURES FOR LAND TREATMENT PROCESSES *

	Principal Processes		
Feature	Irrigation	Overland Flow	Rapid Infiltration
Application techniques	Sprinkler or Surface[a]	Sprinkler or	Usually surface
Annual application rate (feet)	2 to 20	10 to 70	20 to 550
Field area required (acres)[b]	56 to 560	16 to 110	2 to 56
Typical weekly application rate (inches)	0.5 to 4	2.5 to 6[c] 6 to 16[d]	4 to 120
Minimum preapplication treatment provided in United States	Primary sedimentation[e]	Screening and grit removal	Primary sedimentation
Disposition of applied wastewater	Evapotranspiration and percolation	Surface runoff and evapotranspiration with some percolation	Mainly percolation
Need for vegetation	Required	Required	Optional

a. Includes ridge-and-furrow and border strip.
b. Field area in acres not including buffer area, roads, or ditches for 1 MGD flow.
c. Range for application of screened wastewater.
d. Range for application of lagoon and secondary effluent.
e. Depends on the use of the effluent and the type of crop.

Source: EPA Process Design Manual for Land Treatment of Municipal Wastewater, 1977.

TABLE G-2

COMPARISON OF SITE CHARACTERISTICS FOR LAND TREATMENT PROCESSES

Characteristics	Principal Processes: Irrigation	Overland Flow	Rapid Infiltration
Slope	Less than 20% on cultivated land; less than 40% on noncultivated land	Finished slopes 2 to 8%	Not critical; excessive slopes require much earthwork
Soil permeability	Moderately slow to moderately rapid	Slow (clays, silts & soils w/impermeable barriers)	Rapid (sands, loamy sands)
Depth to groundwater	2 to 3 ft (minimum	Not critical	10 ft (lesser depths are acceptable where underdrainage is provided)
Climatic restrictions	Storage often needed for cold weather and precipitation	Storage often needed for cold weather	None (possibly modify operation in cold weather)

Source: EPA Process Design Manual for Land Treatment of Municipal Wastewater, 1977.

Depth and Permeability of Soil

Soil depth and permeability is an important consideration in examining the feasibility of an irrigation system because it directly affects the liquid loading rate of effluent. A minimum depth which permits free drainage is required for most types of crops. Furthermore, renovation of wastewater occurs generally after passage through the first two to four feet of soil. This depth will vary dependent upon extent of root development, soil permeability and wastewater renovation requirement. Table G-2 shows that a moderately slow (clay loams) to moderately rapid (sandy loams) permeability is desirable for an irrigation type system. Generally, a soil capable of infiltrating two inches/day or greater falls in this category.

Depth to Groundwater

A minimum depth to the groundwater table is desirable to ensure aerobic conditions. Acceptable values for this depth are generally two to three feet although this value may be greater depending upon specific site conditions. Groundwater quality is another critical factor in any land application system, particularly in instances where it is close to the surface. Discussion of this topic is found in a later section on the collection systems.

Vegetative Cover

Preferably, slopes should be limited to less than 20 percent on cultivated land and less than 40 percent on non-cultivated land (forestland). When using the irrigation approach, proper crop management is an important factor. Selection will depend upon two major factors, nutrient uptake and application rates. In many cases, nitrogen uptake is a primary concern. Nitrate buildup in soils could adversely effect subsoil and possibly groundwater quality. This will be further discussed in later sections. In addition to nitrogen uptake, selection of crops should be based upon high water uptake, salt or boron tolerance, market value, or management requirements.

When considering vegetative cover, a factor to keep in mind is the required drying out period. This period can vary from several hours per day to several weeks. Certain vegetative cover which require less time for drying out may be more desirable. A shorter drying out period allows for a longer application rate which could result in greater quantities being applied. Generally, a ratio of drying to wetting of three or four to one is an acceptable minimum.

Overland Flow

As depicted in Figure G-1, overland flow is the controlled discharge of effluent onto land with a large percentage of the wastewater appearing as runoff. Generally, this type of system is used when soils with low infiltration/percolation rates are present. Requirements of the system involve filtering action of a close growing vegetation (generally adaptable grasses) and the controlled flow of a thin film of wastewater over the surface. Like irrigation, several criteria are necessary to satisfy the requirements for an efficient system.

Depth and Permeability of Soil

As evident from the introductory remarks, soil depth is not a critical design factor. Permeability is a more critical factor. Soil types can vary from clays to silt loams. These soils generally have impermeable barriers which are a necessity for this type of application. Because groundwater is not likely to be affected by overland flow, it is only of minor concern in site selection.

Slope Conditions

Topography is an important design factor when determining the feasibility of an overland flow system. Slopes should range from two to six percent and the ground should have a smooth surface. This allows the wastewater to flow in a uniform sheet. If slopes are greater than eight percent, problems such as erosion, difficulty in utilizing farm machinery and a general reduction of the filtering efficiency may occur.

Other Management Practices

In addition to physical conditions, some management techniques are necessary to ensure proper application. These techniques include: maintenance of proper hydraulic loading cycle, maintenance of an active biota and growing grass, and monitoring the performance of the system. These techniques will assure proper renovation of wastewater.

Rapid Infiltration

This type of system is most common when groundwater recharge or recovery of water is desired. Like irrigation, most of the applied wastewater percolates through the soil and the treated effluent eventually reaches the groundwater. Unlike irrigation, vegetation is not required. The wastewater is applied to rapidly permeable soils via spreading basins or sprinkling systems and is purified as it travels through the soil matrix (Figure G-1). Description of the necessary conditions follows.

Depth and Permeability of Soil

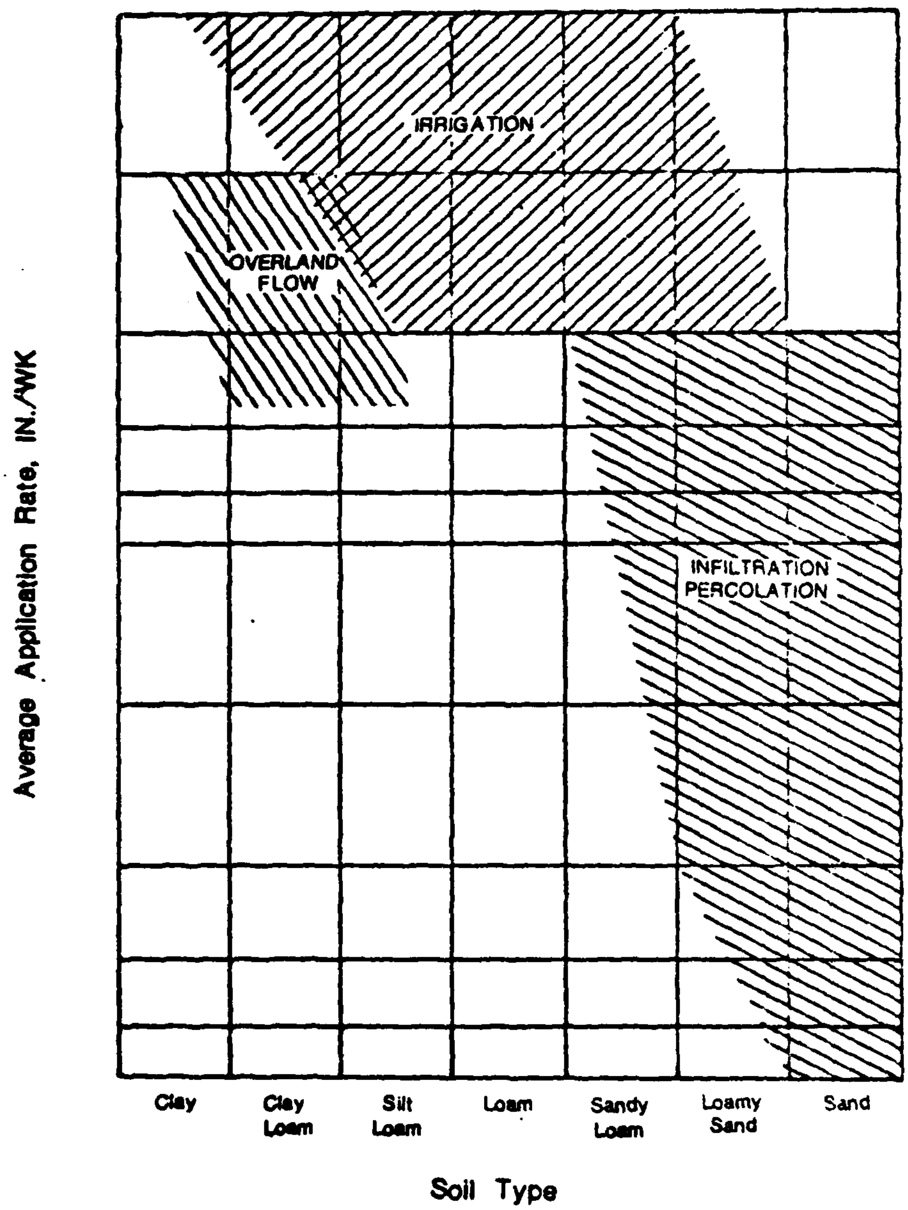
Soil permeability is an important design criteria for this application approach. Unlike the other two approaches, a soil with rapid permeablity is desirable. The soil types include sands and loamy sands. Figure G-2 graphically shows the range of loading rates and soil types for this process. The depth of the soil in this approach is highly variable. Generally, a depth of ten feet is desired although a smaller depth is feasible if proper management is used.

Slope Conditions

The topography in the area is not a critical design factor. In general, slopes should not be excessive or earthwork may have to be done. Geologic conditions are somewhat more critical than topographic ones. Since groundwater can be directly affected, aquifer conditions should be traced. Monitoring of the groundwater should take place to guarantee pollution does not occur.

FIGURE G-2

SOIL VERSUS APPLICATION RATE



Other Management Practices

Other management practices include maintenance of hydraulic loading cycles, basin subsurface management, and general system monitoring. Careful management of wastewater loading rates is critical to assure that saturation does not occur. This may require the occasional shut-off of the system.

APPLICATION CRITERIA

In order to successfully use land application as a viable technique, specific criteria must be met. Full understanding of the method of application, proper rate of application, and proper application season is required. Brief descriptions of the necessary requirements for each of these criteria follow.

Method of Application

There are three basic methods of applying wastewater to lands: spraying, ridge and furrow and flooding. Figure G-3 gives a visual description of these methods. The method known as spraying or sprinkling can be accurately compared with rainfall. The technique involves forcing of the effluent via pressure to emanate over the designated area. The spray is delivered from nozzles or sprinkler heads and discharge rates are controlled by either adjusting the pressure or varying the aperture size. The advantage of this type of operation mode is its flexibility in suitable ground configurations. In addition the system has the advantage of adapting to either being stationary or moveable. A third advantage is the uniform distribution of waste that is achieved using this method. Disadvantages of this method include its high cost. The factors behind the high costs include pump and piping costs and pump operation costs. A second disadvantage is its inability to accommodate large solids in the effluent thus requiring the waste to contain solids small enough to pass through the nozzles without clogging them.

A second application method is flooding. As the term implies, flooding is the inundation of land with a certain depth of effluent. Two factors influence the depth of flooding - vegetative cover and soil permeability. Three techniques are available for application: border strip, contour check, and ridge and furrow. These techniques vary in slope, quantity of land necessary, and method of operation. Disadvantages of this flooding method are three-fold. The available land must be relatively flat to assure uniform flooding. In addition, the land may require drying out periods, although this requirement may also be necessary with the other methods. Finally, crop selection may be more difficult because the vegetative cover must be able to withstand periodic flooding.

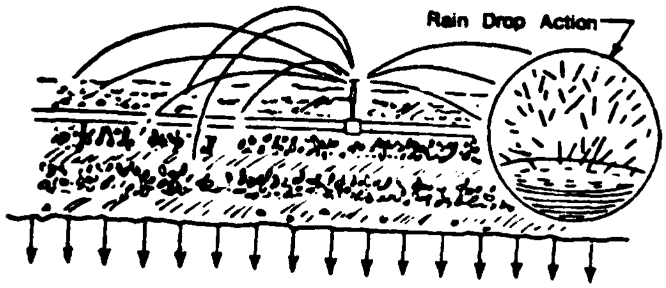
The ridge and furrow method is accomplished by gravity flow whereby the effluent flows in the furrows and then seeps into the ground. The ground, although relatively level, is groomed into alternating ridges and furrows which have varying widths and depths dependent upon quantity of effluent and soil composition. Like flooding, a disadvantage of this method is the necessity for drying out periods. Also, crops should be carefully selected for proper management.

Rate of Application

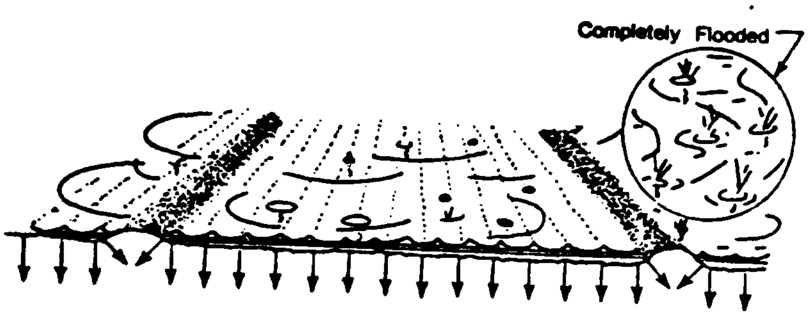
The correct rate of application is dependent upon a number of factors: soil texture, vegetative cover if any, and topography. The soil texture is perhaps one of the more critical criterion in determining application rate. The soil's permeability will also effect

FIGURE G-3

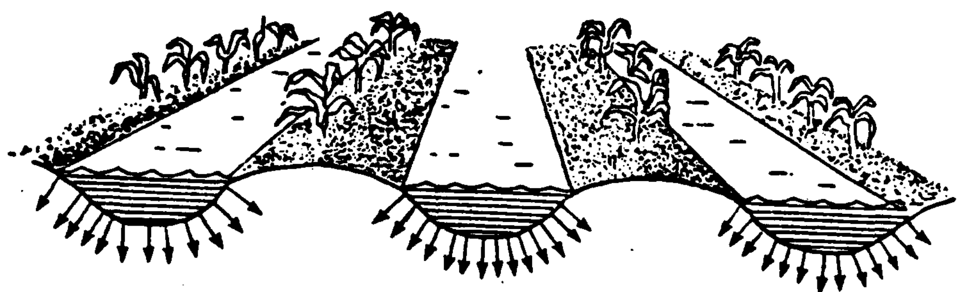
BASIC METHODS OF APPLICATION



(a) Sprinkler



(b) Flooding



(c) Ridge And Furrow

the decision on what application process to use. Figure G-2 illustrates the various loading rates for different soils and indicates that the less permeable soils such as clays to sandy loam, generally require a slower application rate.

A second important criterion in determining rate of application is the selection of vegetative cover. Not only is this important in selecting a mode of operation (spraying, flooding, or ridge and furrow) but it also plays a significant role in determining nitrogen loading rates. Nitrogen has a significant effect upon the environment and often limited quantities are desirable. Certain crops have a greater capacity for "nitrogen uptake" which may in turn allow a higher application rate. Table G-3 lists the various uptake rates for selected crops. Climatic variations also play a role in determining the type of vegetative cover.

TABLE G-3

CROP UPTAKE OF NITROGEN

Crop	Nitrogen Uptake (lb/acre/yr)
Alfalfa	155-220
Coastal bermuda grass	480-600
Corn	155
Red clover	120
Reed canary grass	226
Soybeans	99-113
Wheat	62-76

Source: EPA Process Design Manual for Land Treatment of Municipal Wastewater, 1977.

A final criterion in determining the rate of application is topography. Generally land application is more effective on gentle slopes than on steep slopes depending on the rate of application, cover, and soil characteristics. Slope conditions also play a critical role in the type of application procedure which can be implemented in a given terrain.

Application Season

Using the correct application is an important criterion in proper management of a land application system. Regional climatic conditions exert a large influence on this determination. Such conditions include variations in temperature, evapotranspiration, precipitation and/or wind. These factors may directly or indirectly influence: water balance, length of growing season, number of days when system is operable, storage capacity requirement, and rate of stormwater runoff. Table G-4 summarizes the climatic data required for land application systems.

COLLECTION SYSTEMS

Traditionally, collection systems for land application sites are used as preventative means to protect the groundwater table from oversaturation or contamination. They can be of value, when properly designed, to recover, for subsequent use, effluent that has passed through the soil matrix. In this study, the latter use will be investigated. Since

TABLE G-4

SUMMARY OF CLIMATIC ANALYSES
FOR LAND APPLICATION

FACTOR	DATA REQUIRED	ANALYSIS	USE FOR LAND APPLICATION
Precipitation	Average annual, maximum, minimum	Frequency analysis (in/yr)	Water balance determination
Rainfall Storm	Intensity, duration	Frequency analysis (in/day)	Runoff estimate
Temperature	Days with average below freezing	Frost free period (day)	Storage, treatment efficiency, crop growing season
Wind	Velocity & direction	Frequency analysis (speed and direction)	Cessation of sprinkling

collection of renovated wastewater for use is uncommon, little information is available in the literature regarding this process. Two types of collection methods, however, have been used for recovery of renovated wastewater: underdrain systems and pumped withdrawal. These systems vary significantly in design; however, they achieve similar results.

Underdrain systems consist of a series of tiles placed below the filter zone to collect the renovated effluent. The tiles may be aligned to allow the recovered water to be rapidly transmitted to a common point of discharge or withdrawal. The tile can be made from a variety of materials including plastics, concretes, and clays. The choice is generally based on local price.

For irrigation-type systems, underdrains are most useful in assuring that the soil does not become oversaturated. To assure proper drainage and maximum recovery, both the spacing and depth of the tile system are critical and must be evaluated on an individual site basis. Rapid infiltration systems are the most conducive land application process for recovery.

Pumped withdrawal, although used almost exclusively in the case of the infiltration approach is the least often used of the three application systems. The method essentially involves the recharging of the water table and subsequent withdrawal using recovery wells. Generally, the method is only economical when the aquifer is greater than 15 feet from the surface and permeable enough to allow pumping. With either scheme groundwater monitoring is needed facilitated to ensure the safety of the recovered water. Since water quality is important, periodic testing of routine substances including BOD, DO, and pH, as well as toxic substances, is necessary.

LAND APPLICATION AS A POTENTIAL WATER SUPPLY SOURCE

Given the previous description of the general conditions which affect land application, the purpose of the following sections is to evaluate the conditions which govern the feasibility of land application within the MWA. Included is a summary of both active and studied land application sites within the MWA. This summary provides an indication of the magnitude of active land application sites in the region and local experiences regarding the potential for future sites. These sections are followed by a series of discussions on several factors which have a direct bearing on the viability of land application for water supply within the MWA.

Land Application Sites Within the MWA

Through 1980 there were three application sites in operation within the MWA. They are: the Oak Ridge Estates and the Occoquan Forest sites in Prince William County, Virginia, and the St. Charles City site in Charles County, Maryland (Figure G-4). The sites are used exclusively for wastewater disposal for small communities and contain no elements for planned water supply reuse. The following sections briefly describe these sites and any problems associated with these facilities.

Oak Ridge Estates Site

As seen from Figure G-4, the Oak Ridge Estates facility is located in the southern portion of Prince William County. The facility uses the irrigation approach and the effluent is applied via spray nozzles. Initially, the facility had difficulty with springs infiltrating into the holding ponds and being able to maintain adequate vegetation in the spray area. Criticism of the site also stemmed from its infrequent monitoring program. These programs have since been corrected and the state permits 0.088 MGD to be applied to the area. Due to the limited capacity of the site and its distance from the Potomac River, it could not be used to make any major contribution to the supply of water in the MWA.

Occoquan Forest Site

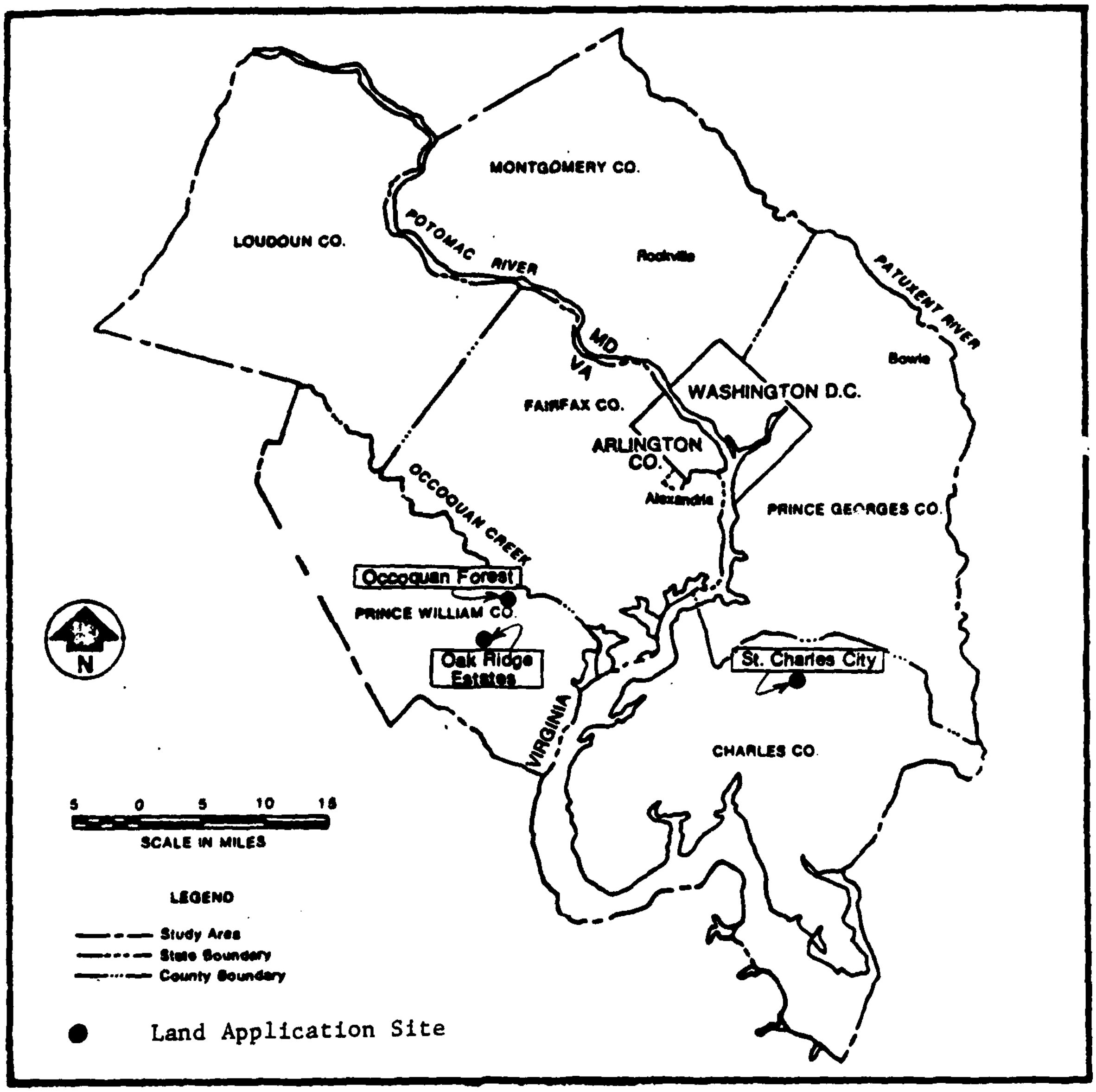
The second site, Occoquan Forest, is also located within Prince William County just northeast of the Oak Ridge Estates facility. Like the Oak Ridge Estates site, the irrigation approach is utilized. Effluent is sprayed onto forestland via nozzles at a permitted rate of 0.54 MGD. Presently, 0.088 MGD is applied. The secondary treated effluent is delivered from a holding pond when the pond reaches a specified elevation. The bottom of the pond has been sealed with clay to assure that there is no leakage into the surrounding soil. All of the applied effluent must be absorbed by the spray area. If leakage occurs to surrounding areas, it must be reported to appropriate state officials immediately. Again, like the Oak Ridge Estates facility, its use as a water supply source is limited due to its small size and remoteness from the Potomac River.

St. Charles City Site

This site, located in the northern portion of Charles County, is like the other two sites in that it utilizes the irrigation approach. It serves a community consisting of approximately 1500 residences and is allowed to apply up to 1.2 MGD. For the past ten to twelve years, approximately 0.75 MGD has been applied.

FIGURE G-4

LOCATION OF LAND APPLICATION SITES
WITHIN THE MWA



The facility consists of a series of aerated lagoons that have a one year retention capacity. The lagoons cover an area of 20 acres. The effluent is then sprayed on nearby woodland. The effluent receives chlorination before it is applied to the land. No additional treatment is utilized other than aeration. Spray periods are regulated on a manual basis and, thus far, the facility has proved to be a successful approach for wastewater disposal. It is interesting to note that water-loving vegetation has appeared in the immediate spray area. Furthermore, natural bacterial processes within the lagoons have greatly reduced the amount of sludge disposal which is necessary. Again, because of its limited capacity, it is unlikely that this facility could be of any significant water supply use in the MWA.

Studies of MWA Land Application Sites

In addition to the existing sites, there have been studies conducted to examine the feasibility of implementing additional application systems within the MWA. Four major studies are noteworthy, two county reports, a report examining the feasibility of land application throughout the MWA, and a draft report on a Metropolitan Washington Water Quality Management Plan. Like the present sites, the county reports have only examined land application systems for wastewater disposal. They deal primarily with systems that could provide a means of disposal for small communities and make a major contribution towards advanced wastewater treatment (AWT). The third study actually examined the feasibility of utilizing land application as an alternative for collecting water. A summary highlighting pertinent aspects of the studies follows.

Prince Georges County

In 1977, Metcalf & Eddy - Sheaffer & Roland reported on a Preliminary Assessment Feasibility of Land Treatment of Wastewater in Prince Georges County, Maryland. The basic purpose of this report was to identify opportunities for land treatment of wastewater within Prince Georges County and to evaluate the alternatives enabling the County to reach a decision concerning acceptable forms of AWT. Specific objectives within the report included: a review of previous reports; evaluation of the various land treatment techniques; determination of any necessary requirements; review of the existing information base and identification of any data needs; identification and evaluation of specific site locations; and a preliminary comparative cost analysis. It is important to note that the study was not intended to serve as a design report. In identifying potential areas the report considered both technical and social implications relating to land application systems. Twelve sites were identified and their locations are shown in Figure G-5. The application sites are generally located at the extremities of the county within rural greenbelt areas. The twelve sites were then combined into a series of five alternatives that ranged in capacity from 20 to 56 MGD. Table G-5 lists some of the important characteristics associated with the various groups. From this table one can conclude that the potential for utilizing all three approaches exists. The quantity of land required is appreciable, varying from approximately 5,000 to 17,000 acres. None of the systems used the treated wastewater directly; however, some of the alternatives, such as those using the rapid infiltration approach, would be adaptable for this purpose.

The study concluded that "... the evaluation has not been conclusive. Rather, important factors and preliminary indications have been highlighted that must be considered in deciding which alternatives are to be developed." Some preliminary cost analysis was presented which showed that in most cases land treatment was a cost-effective

alternative when compared with other AWT processes. The report also indicated that environmental and social questions would have to be addressed before sites could be developed. These questions include water quality and public acceptance of land application systems. To date, no action has been taken to implement application systems. At the present time, treatment capability services provide all necessary treatment to the year 2000. However, the study did encourage further investigation of this type of treatment process when examining methods of AWT within Prince Georges County.

Montgomery County

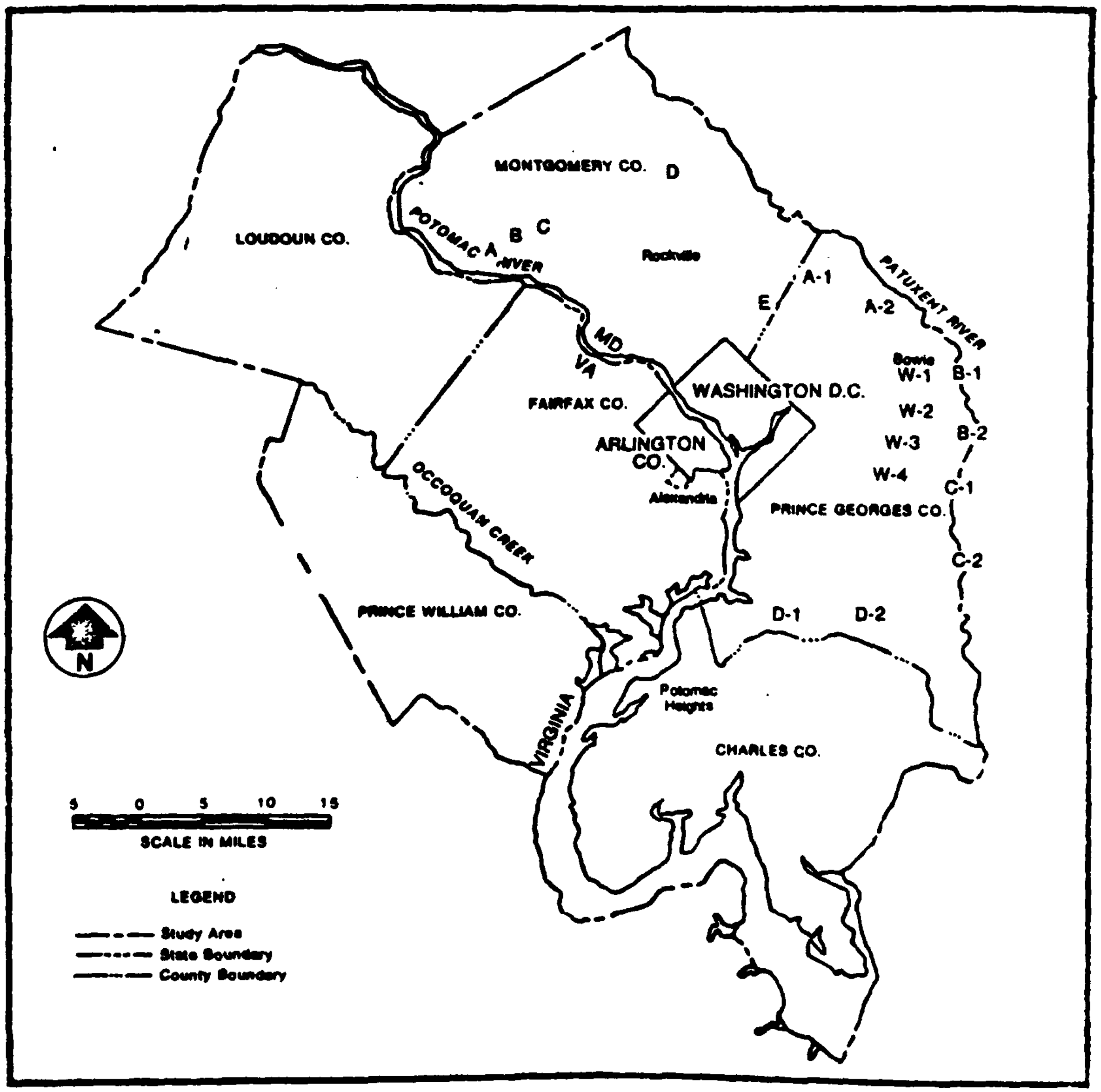
In 1977, the Metcalf & Eddy - Shaeffer & Roland group prepared a companion report to the Prince Georges Study. The Feasibility of Land Treatment of Wastewater in Montgomery County, Maryland identified systems geared toward renovation of wastewater only, and contained no detailed design information. Five potential site locations were identified within Montgomery County as shown in Figure G-5. The majority of the sites were located in the outlying portions of the County away from the highly developed regions. From these sites, eight treatment options were considered. Table G-6 gives a synopsis of these options and a brief description of the design elements. As evident from this table, the design capacity of these systems is much less than those proposed for Prince Georges County. The largest of the application options, Dawsonville/River Road, has a capacity to treat 15 MGD which is 5 MGD below the estimated minimum available from the Prince Georges County sites. Correspondingly, the quantity of required land is also diminished, to a maximum of 6,000 acres. The Columbia Pike site might be the simplest to implement with a collection system, since it uses a rapid infiltration approach; however, it represents one of the smaller sites studied in the report.

The River Road and Dawsonville sites which are both located above the MWA Potomac intakes have the potential for augmenting Potomac River flows by as much as 15 mgd (Table G-6 Moderate Treatment Option A & B). Although the study indicated that the quality of the renovated water from these sites would be of equal or higher quality than the Potomac River, the treatment areas have been termed unacceptable by local interests. Disapproval by the public stemmed from their concern of impacts of such a system on water supply for the MWA.

Table G-6 also shows the cost effectiveness of land treatment in relation to AWT for Montgomery County. The report shows that for the 1977 costs, the total cost of land treatment varies from 40 to 85 percent when compared with AWT systems at the same site. It is important to recognize that if the sites are identical, land cost does not enter into the comparison. The report recommended that further investigations into this type of system be conducted. To date, no action has been taken toward implementing the land treatment options discussed in the report. WSSC officials have indicated that the land treatment options discussed in this report have been dismissed for two basic reasons: (1) escalating land costs within the county, and (2) a fear of the uncertain long term reliability using this type of treatment.

FIGURE G-5

PROPOSED APPLICATION SITES FROM
PREVIOUS REPORTS



NOTE: Sites identified can be correlated to Tables G-5 and G-6.

TABLE G-5

MAJOR LAND TREATMENT ALTERNATIVE GROUPS IN PRINCE GEORGES COUNTY

ALTERNATIVE GROUP	DESCRIPTION	PREAPPLICATION TREATMENT	LAND TREATMENT PROCESS	THEORETICAL RANGE OF MAXIMUM CAPACITY MGD[a]	COMBINED SITE AREAS, ACRES[b]	REMARKS
1	Treatment of flow from either Upper Anacostia Basin and/or Parkway STP at Anacostia sites (A-1, A-2)	Aerated lagoons at site, or Parkway STP	Rapid infiltration, overland flow, irrigation, or combinations	20-49	5,280	Primarily to surface streams of Anacostia Basin. Some aquifer recharge.
2	Treatment of Upper Western Branch or Bowie flows at Upper Basin sites (W-1, W-2, W-3, W-4, B-1, B-2)	Aerated lagoons at site, or Bowie STP	Primarily irrigation	43	14,670	Primarily to surface streams of Western Branch and Patuxent basins. Some aquifer recharge.
3	Advanced waste treatment of secondary effluent from Western Branch STP at Sites (C1, C-2, W-3, or B-2)	Western Branch STP	Rapid infiltration, irrigation	30-48	15,090	Primarily to surface streams of Western Branch and Patuxent basins.
4	Treatment of flows from Upper Anacostia Basin via pumpover to Upper Western Branch Sites (W-1, W-2, W-3, B-1, B-2)	Aerated lagoons in Upper Western Branch	Primarily irrigation	39	16,990	Primarily to surface streams of Western Branch and Patuxent basins. Some aquifer recharge.
5	Treatment of flows from Mattawoman Basin and/or Piscataway STP at Mattawoman sites (D-1, D-2)	Aerated lagoons at site or Piscataway STP	Primarily overland flow	39-56	5,770	To silvicultural agricultural reuse project or Piscataway outfall.

a. Assumes full utilization of each site within alternative groups.
b. Probable required land area includes application area plus 25% allowance for buffer zones and other uses but does not include an allowance for preapplication treatment and storage.

TABLE G-6

SUMMARY OF MID-TERM LAND TREATMENT OPTIONS IN MONTGOMERY COUNTY

SITE AND OPTION	DESIGN CAPACITY, Mgd	AREA, ACRES	TYPE OF LAND TREATMENT	WASTEWATER SOURCES BASIN	ESTIMATED TOTAL[a] COST, $1,000 GAL (1977 DOLLARS) LAND TREATMENT	EQUIVALENT AWT
High level treatment						
River Road Option A	5.0	2,200	Standard rate irrigation	Seneca	1.34	3.17
Dawsonville Option B[b]	5.0	3,189	Slow rate irrigation	Seneca	1.70	3.17
Option B[c]	5.0	3,189	Slow rate irrigation	Seneca	1.55	3.17
South Germantown Option C	2.0	910	Slow rate irrigation, standard rate irrigation	Seneca	2.14	4.70
Muncaster Road Option D	10.0	4,097	Standard rate irrigation	Rock Creek	1.34	2.56
Columbia Pike Option E	4.0	664	Overland flow, rapid infiltration	Northwest Branch	1.35	3.34
Moderate level treatment						
River Road Option A	14.0	3,189	Standard rate irrigation, overland flow	Seneca Muddy Branch	0.94	1.11
Dawsonville/ River Road Option B	15.0	6,000	Slow rate irrigation, standard rate irrigation, overland flow	Seneca Muddy Branch	1.11	1.69

a. Total cost includes amortized capital plus operating and maintenance costs. Local costs would be less if federal and state assistance is available.
b. Pretreatment prior to land application would occur at existing Seneca plant.
c. Pretreatment prior to land application would occur at a facility located at the Dawsonville site.

Northeastern United States Water Supply Study, 1975

Under PL 89-298, the North Atlantic Division, U.S. Army Corps of Engineers, conducted the Northeastern United States Water Supply (NEWS) Study in which the Metropolitan Washington, DC Area was identified as one of several areas with potential water supply problems. Land application with a water supply purpose was among several alternative project types considered in the study. The design goal for the study was to provide an additional 25 MGD to the Potomac River during low flow periods using a collection system depicted in Figure G-6.

Several criteria were used in selecting a potential land application site including: 1) adequate land area, 2) proximity to wastewater source, and proximity to discharge point on the Potomac River upstream of the Washington, D.C. water supply intakes. Using these criteria, a land treatment site was specified near Lovettsville in northeastern Loudoun County. The wastewater source was the Potomac interceptor at the Loudoun County-Fairfax County border. Raw wastes from this location would be pumped to a lagoon system providing secondary level treatment, to storage facilities to retain the treated wastewater during frost periods and then to a 4,590 acre land treatment site. A tile collection system was proposed from which the renovated wastewater would be pumped to the Potomac River.

The total construction cost of the system escalated to October 1981 price levels is estimated at $326 million. In conducting the analysis, it was noted that land costs could escalate if future expansion occurred. This fact was taken into consideration when evaluating the overall feasibility of the project.

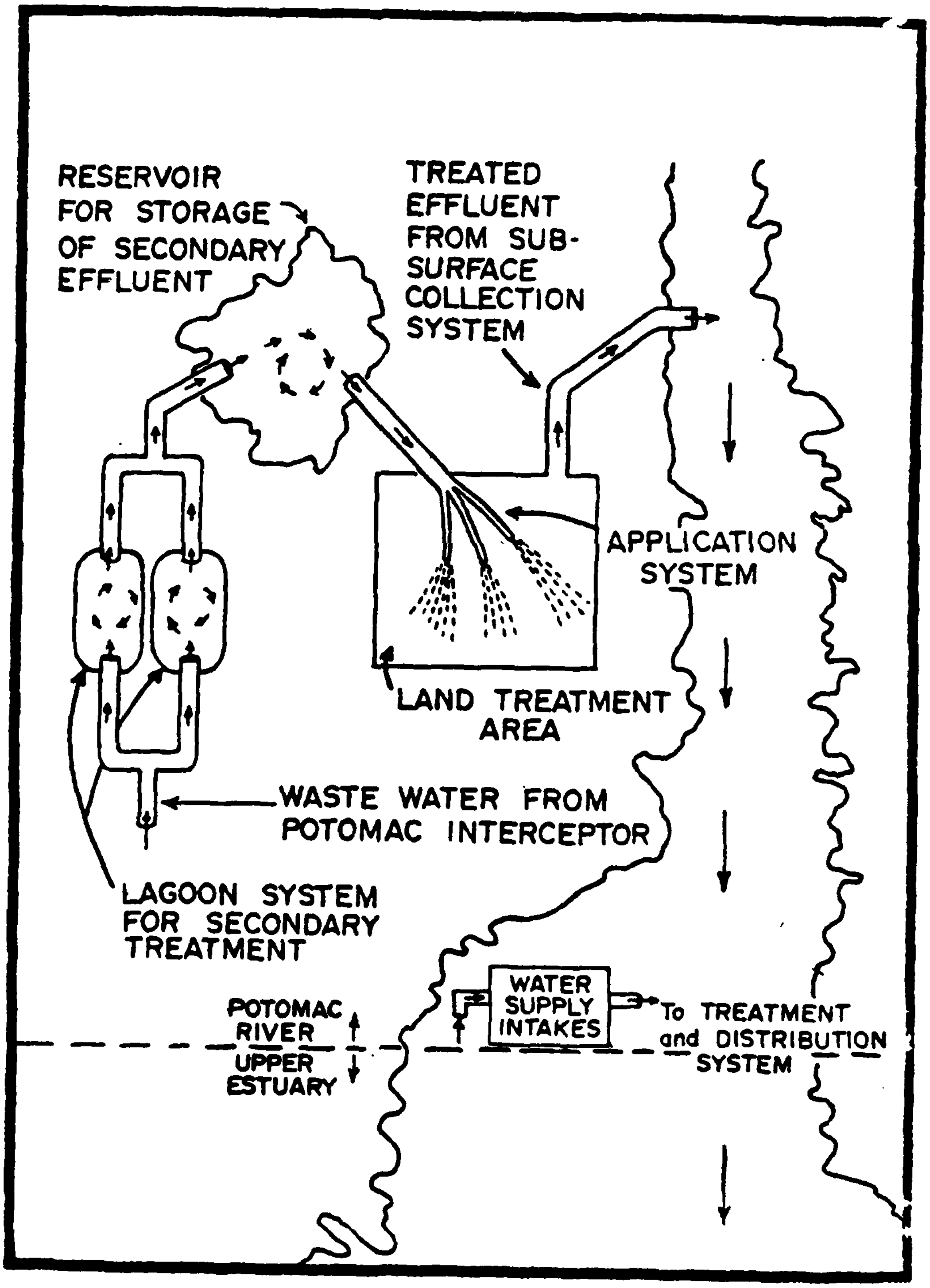
Draft Metropolitan Washington Water Quality Management Plan

Planning in the MWA under Section 208 of the 1972 Federal Water Pollution Control Act Amendments began in 1975 after the MWCOG was assigned to carry out the requirements set by law. Within the March 1978 Draft Water Quality Management Plan for the MWA, land application was investigated as a potential mechanism for advanced waste treatment. Since there were some ongoing studies as well as some past studies where land treatment was being considered for future capacity, land application was viewed as a real possibility in the future.

The study summarized four different options ranging from giving equal and adequate consideration to land treatment in all 201 Step I studies to a mandatory use of land treatment for all new sewage capacity in the region. The Water Resources Planning Board (WRPB) and the Technical Advisory Committee endorsed Option II which represented equal and adequate consideration in all 201 Step I studies with public education to encourage land treatment. The WRPB was further concerned that each waste treatment system be considered on its own merit as detailed studies were undertaken. The Citizen Committee endorsed options which encouraged policies to land treat all new discharges where feasible. While discussing the various options, a number of items were noted. Among them was the estimate that 330 acres are necessary per MGD of effluent. It was noted that the level of treatment was compatible with the then current NPDES permits and also that land treatment often preserved open spaces.

FIGURE G-6

REPRESENTATION OF LAND TREATMENT
PROJECT OPERATION



The impacts of land treatment cited were largely positive. Economic benefits could be derived from using land treatment over more conventional treatment methods. The systems could also enhance vegetation. Furthermore, as a result of land treatment, direct water discharges could be reduced and stream water quality improved. Negative impacts cited included contamination from toxics, carcinogens, viruses and heavy metals. Although this approach could effect a swiftly moving aquatic system from direct AWT discharge, damage to groundwater from land application could be more difficult to treat.

The study noted that this approach would result in a reduction in both the quantity of sludge and energy costs. While the quantity of sludge will be reduced independent of specific site, energy costs will vary on a more site specific basis. One of the major factors which affected the cost for the land treatment system was the land requirements. In addition to the treated acreage, an additional 4,151 acres would be required for the wastewater treatment facilities, storage areas, and buffer areas.

The study concluded that land application was an "unattractive" alternative water supply source. The conclusion was based upon high construction and operation costs and adverse environmental and socioeconomic disruptions in the County.

Factors Affecting Land Application in the MWA

Several physical, social and economic factors are important determinants for land application in the MWA. Climate, soil, and land use conditions are discussed in the following sections because they can pose limitations on the location and size of potential land application sites in the region. In addition, two factors which would exert a major influence are discussed, including the proximity of an effluent source to a feasible application site and the proximity of that land application site to a discharge point along the Potomac River.

Climate

Rainfall, temperature, and wind data from recording stations at Dulles International Airport and Washington National Airport provided representative climatic data for the MWA which are summarized by monthly totals in Table G-7. Several conclusions can be drawn from these data. During the winter months of December through March, land application would be limited because of the likelihood of periods of frozen ground. The remaining frost free months of the year would serve as the application season although excessive rainfall during the spring could greatly limit this possibility. Given the area's temperature and rainfall characteristics, some type of storage facilities would be required to store effluent during the undesirable application periods. Favorable precipitation conditions are likely to persist, however, during the summer months which coincide with low flow in the Potomac River. During these periods, the potential for land application and the need for low flow augmentation in the Potomac would be the greatest.

Soil Characteristics

As evident from earlier sections, soils are important factors affecting the design of land treatment systems as they directly influence the loading rates and, therefore, the potential capacity of a system. An examination of the soils in the MWA indicates there are seven geology-related soils types which are comprised of some 20 soil associations. The first group, soils upon crystalline rock of the Piedmont and Blue Ridge, accounts for slightly more than 50

TABLE G-7

MWA RECORDED CLIMATIC DATA

MONTH	TEMPERATURE (F°)[a] MEAN	TEMPERATURE (F°)[a] MINIMUM	PRECIPITATION MEAN (Inches)	WIND SPEED[b] MEAN	FASTEST mile[c] SPEED
Dulles International Airport					
Jan	30.5	20.8	2.6	8.2	38
Feb	33.2	22.7	2.59	9.2	36
Mar	43.1	31.9	3.22	9.4	40
Apr	52.5	39.9	2.83	9.1	46
May	61.7	49.5	3.5	7.8	39
Jun	70.7	59.0	4.59	6.8	38
Jul	75.3	64.0	3.47	6.3	44
Aug	73.9	62.4	4.13	6.1	35
Sep	66.9	55.4	3.75	6.4	35
Oct	54.7	42.3	3.1	6.7	38
Nov	44.8	33.3	3.04	7.8	35
Dec	35.1	25.7	3.86	7.9	40
Average	53.5	42.9	40.68	7.6	46
Washington National Airport					
Jan	35.7	28.0	2.71	10.0	56
Feb	37.8	29.3	2.46	10.4	57
Mar	46.0	36.8	3.34	10.9	60
Apr	56.3	43.8	2.79	10.5	56
May	65.8	55.9	3.83	9.3	50
Jun	74.5	65.1	3.44	8.8	57
Jul	78.5	69.5	4.11	8.2	54
Aug	77.1	68.3	4.71	8.0	49
Sep	70.5	61.5	3.3	8.2	56
Oct	59.5	49.9	2.92	8.6	78
Nov	48.5	39.8	2.93	9.2	60
Dec	38.4	30.8	3.23	9.5	62
Average	57.4	48.4	39.82	9.3	78

a. Temp. & Precip. Records: Dulles International (1963-1977), Washington National (1972-1978).
b. Wind Records: Dulles International (15 years); Washington National (30 years).
c. Fastest Mile Wind refers to speed fastest observed 1-minute value when direction is in tens of degrees.

percent of the total area. These soils are relatively shallow with loam to silt-loam surface textures. They have been designated as suitable for either agricultural development or urbanization and, therefore, would most likely be adaptable to land application processes.

The second group, soils on sandstone, shale, and conglomerate of Triassic Lowlands, consists mainly of dark red shale. The soils are shallow to moderately deep and portions of this region yield little groundwater. Agricultural development is encouraged, as long as proper management is used. Therefore, there is a small potential of utilizing this area for land application purposes.

The third group, soils on limestone of the Triassic Lowlands, is comprised of soils derived from limestone conglomerate. Surface textures range from gravelly or rocky-silt-loam to silt loam. The area's soils vary with location and, therefore, land application sites would have to be evaluated on a site specific basis.

The fourth group, silt on mixed crystalline rocks and coastal plain sediments, contains soils influenced by both parent materials. The soils are a combination of deposits similar to coastal plain properties and piedmont crystalline rock. This rock is ill-suited for agricultural development and, therefore, the possibility of land application within the area is reduced.

The fifth group, silts on coastal plain sediments, are sandy to clayey in texture and range from excessively to poorly drained. This variation makes an overall evaluation of the group's potential very difficult. Potential sites in this region would have to be located after extensive site investigations. The sixth group, soils on alluvial terraces, is a good gravel source. Here, the land may be utilized for either agricultural development or urbanization. It is, therefore, likely that this region would be suitable for land application purposes. Finally, the soils on flood plains, are obviously susceptable to flooding. Although these soils have been termed acceptable for agricultural purposes, proper management is recommended to avoid potential disasters. These areas would be unacceptable for land application.

From this brief summary, it is apparent that the various soil types in the MWA would have a bearing on the location of a potential land application site. Although some soil types are more preferable than others it must be recognized that wide variations within a soil group occur and that any land application site must be verified with extensive site surveys and soil testing. Furthermore, in many areas where more suitable soils are available, urbanization has precluded their use for other purposes. From a very general viewpoint, it appears that soils in the more western portions of the MWA are better suited for land application sites. However, this conclusion remains tentative and specific land application sites would require verification for design purposes.

Land Requirements

Existing and planned land use in the MWA is a critical consideration in evaluating sites for land application because they play a major role in determining both the location, size, and cost of a potential facility. Because the area is highly developed around the urban center of the District of Columbia, potential sites are only available in the outlying rural regions where proper soil and land use conditions exist. Generally, areas to the west and south have the greatest potential. Agricultural and forested areas are best suited for land application in these areas. Although some greenbelt areas do exist closer to the urban center, their proximity to development, their small size, and their association with floodplain type environments make them less acceptable as application areas.

In order to determine the land area required to produce varying volumes of water from a hypothetical land application site, the following equation derived in the NEWS study was used:

$$\text{Area (areas)} = \frac{\text{Effluent Required (Mg)}}{\text{Precipitation + wastewater applied - evapotranspiration (mg/acre)}}$$

A range of effluent from 10 to 50 MGD was used as well as varying loading rates to produce a series of curves (Figure G-7) which reflect the land requirements for an application area under varying conditions. Precipitation and evapotranspiration data for the month of July were used as well as the lower end of the application scale (Figure G-2) which most closely approximates conditions in the MWA. It was also assumed that 100 percent recovery was possible after losses from evapotranspiration.

From Figure G-7 and Table G-8 two important conclusions can be drawn. The first is that land application requires a substantial area of land that increases significantly with higher yields desired and, second, when possible, higher loading rates greatly reduce the land requirements under a given yield. Furthermore, it must be noted that a significant amount of additional land would be required beyond the application site itself. This could include a buffer area, transmission rights-of-way, storage area, possible treatment area, and associated maintenance facilities.

Based on an average cost of $3,000 and $1,500 for farmland and forestland, respectively, it is evident that a land application site would involve a large cost. For example, for a 50 MGD agricultural site, land cost alone would range from $4.8 to $77.5 million dollars. Although a wide range of costs are possible, it is likely that the costs would tend to fall on the higher side of the curve where the lower loading rates are more realistic. Additional costs relating to construction of the application facilities, storage facilities and collection system would make large scale land application an extremely expensive alternative.

Location of Existing Wastewater and Water Supply Facilities

An important consideration for siting a land application system is the location of the source of available effluent with reference to a potential site and, in a scheme involving augmenting flows in the Potomac, the distance of an appropriate discharge point from the application site to the Potomac River. These factors will affect both the length and the cost of transmission facilities.

The MWA is served by more than a dozen wastewater treatment facilities. They range in size from 0.1 MGD to over 300 MGD. Table G-9 lists the facilities and both their existing and projected capacities. Only four existing plants have a present capacity of over 20 MGD and only five are projected to be expanded above a 30 MGD capacity in the future. Figure G-8 shows the location of the major wastewater treatment facilities in the MWA. The majority of these facilities lie along the Potomac River. The largest of these facilities, the District of Columbia Blue Plains Plant, is located in the southern section of Washington, DC. With the exception of the Western Branch facility located in eastern Prince Georges County, the remaining major facilities are located within the urban area and are distant from potential application sites. Although these facilities would provide an available source of effluent, any scheme using these sources would involve pumping great distances to potential sites, which would involve high pumping and land costs.

FIGURE G-7

REQUIRED ACREAGE GRAPH

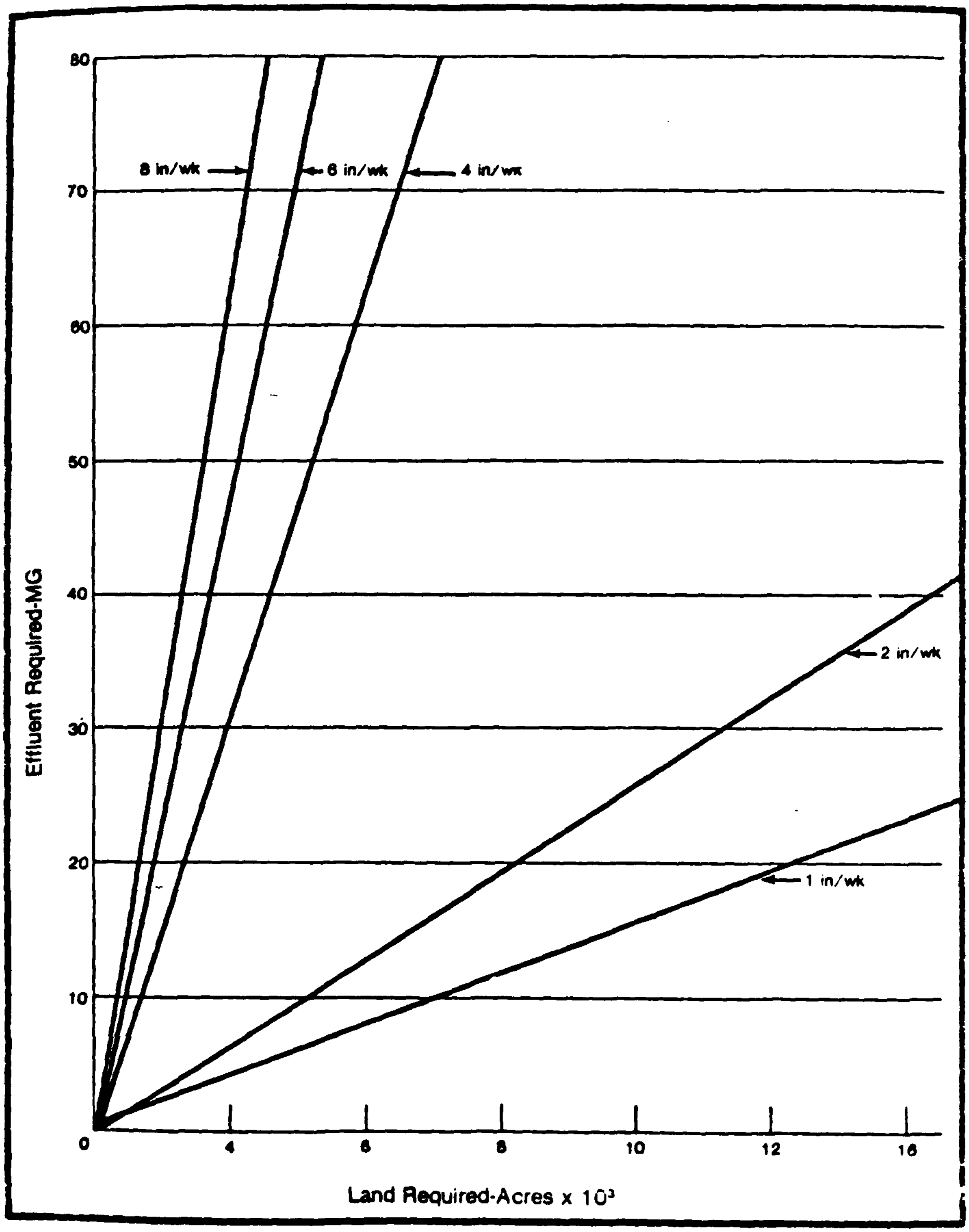


TABLE G-8

REQUIRED ACREAGE FOR VARIOUS EFFLUENT AND LOADING RATES*

Effluent Required MG	Loading Rates Inches/Week				
	1	2	4	6	8
10	5200	3100	650	430	320
20	10300	6200	1300	860	640
30	15500	9300	1922	1290	970
40	20650	12400	2570	1720	1290
50	25800	15500	3220	2150	1610

*Based on 31 days/month.

An alternative to this would be to use sewage from major interceptors in the MWA. However, this alternative would require pre-treatment to secondary levels before application. Withdrawal points along the Potomac Interceptor, the major wastewater pipeline in the region, could be utilized; however, additional costs for treatment would increase the costs of this alternative. After collection, a system designed to augment Potomac River flows during low flow conditions would require a suitable discharge point. The point of discharge would have to be located above the water supply intakes on the Potomac River (Figure G-9).

At the present time, the State of Maryland Environmental Health Administration (EHA) governs the regulation of discharges that impact upon raw water sources used for public supplies. Although renovated water from a land application site could provide an effluent of tertiary level quality, it is questionable as to the location of a discharge point that would be considered acceptable from a public health standpoint. The EHA strongly opposes any discharge point immediately above the Little Falls intakes on the Potomac River and discussions with EHA officials indicate that alternative discharge points would be evaluated in the future on an individual basis. In the past, the EHA approved discharge locations as far above the intakes as the proposed Dickerson site (some 60 river miles upstream), however, future decisions are unknown. One observation bearing on the cost of a land application site is that upstream sites closest to the Potomac River would appear to be desirable. However, the further upstream an acceptable discharge point is located, the higher the transmission costs to convey the raw effluent.

Impacts

Any land application alternative would have environmental, social, and public health impacts. The magnitude of the impacts will vary on a site specific basis although the general impacts will be similar. The environmental components that may be affected by a land-application system include soil, vegetation, groundwater, surface water, animal life, and air quality. The effects on soils include: (1) a decrease in infiltration and percolation rates as a result of clogging by suspended solids, (2) an increase in infiltration and percolation rates due to changing chemical conditions (i.e., change in pH and sodium content of soil), and (3) the possible long-term effect on the soil chemistry due to the build-up of toxic chemicals. The effects on vegetation are usually beneficial. Nitrogen, an important element for the growing cycle, is found in most domestic waste. If proper management techniques are implemented, vegetative growth may be enhanced which in agricultural areas, might increase production.

The groundwater quality and level may also be affected by land application systems. Wastewater constituents not used by the plants, degraded by microorganisms, or fixed in the soil may leach to the groundwater table. Surface water may be affected by (1) discharge from an overland flow system, (2) seepage from an infiltration-percolation system or (3) surface runoff. Use of a collection system would facilitate monitoring of the recovered water and thus decrease the risk of pollution. There may also be changes to the terrestrial or aquatic species. Beneficial effects, such as an increase in forage should be compared to adverse effects such as the possible degradation of aquatic habitat due to changes in surface water quality.

TABLE G-9

WASTEWATER TREATMENT FACILITIES[1]

FACILITY	CAPACITY (MGD)	EXPANSION PROPOSED
District of Columbia Blue Plains	240	309
Piscataway	30	--
Western Branch	15	30
Belair Bowie	2.65	--
Horsepen	**	--
Parkway	7.5	12.5
Pentagon	**	--
Arlington	24	30
Alexandria	27	54
Westgate	13.7	--
Little Hunting Creek	6.6[2]	--
Dogue Creek	5[2]	--
Lower Potomac	18	36
Greater Manassas	**	--
Dale City	**	--
Leesburg	**	--
Occoquan-Woodbridge	**	--
Dumfries Triangle Melrose Gardens	**[2]	--
Fort Belvoir	3.0[2]	--

1. 1978 base data.
2. Facilities abandoned when Lower Potomac Facilities were expanded.
**These seven treatment facilities have a combined capacity of 25.0 MGD.

FIGURE G-8

MAJOR WASTEWATER TREATMENT PLANTS

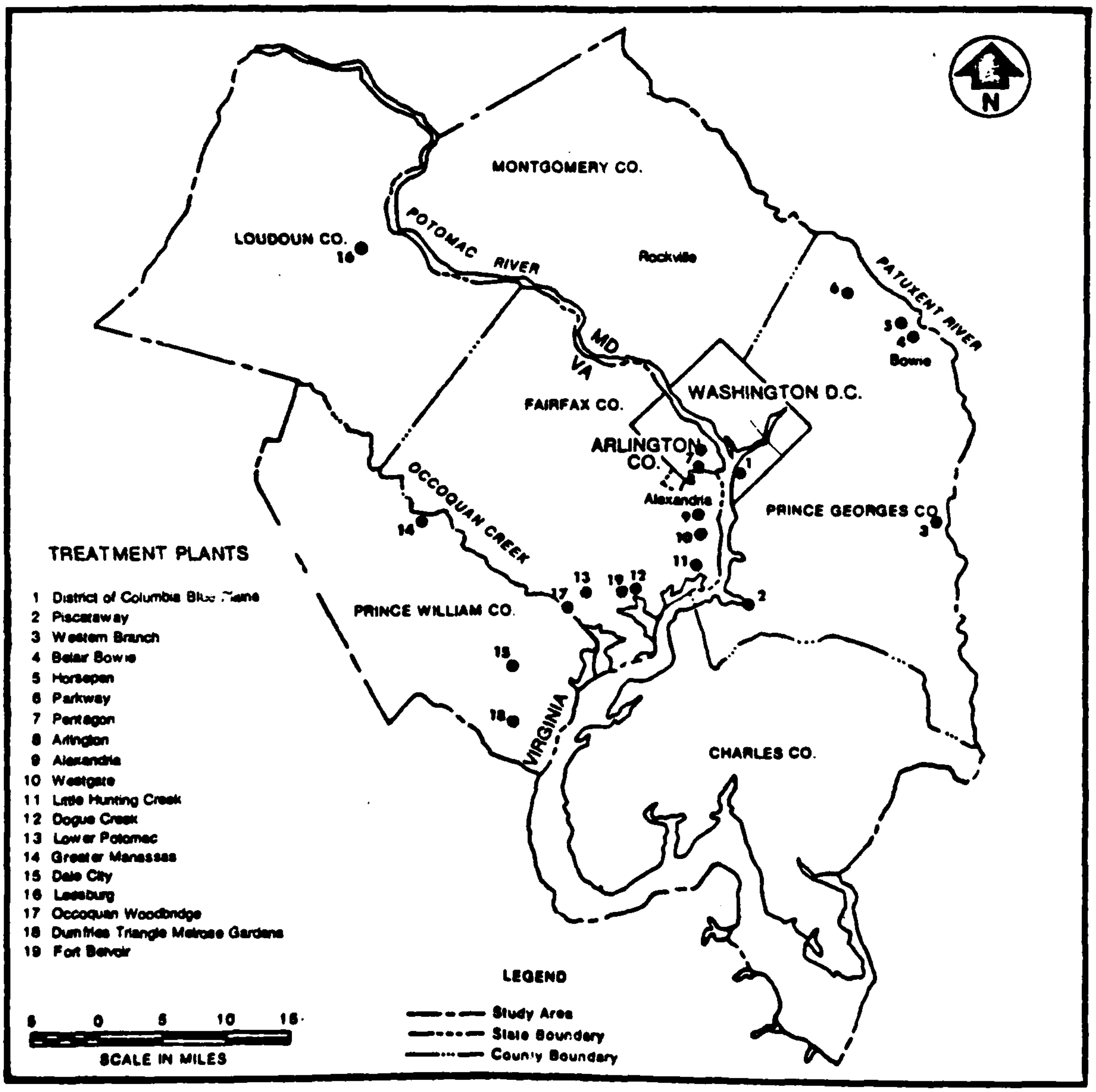
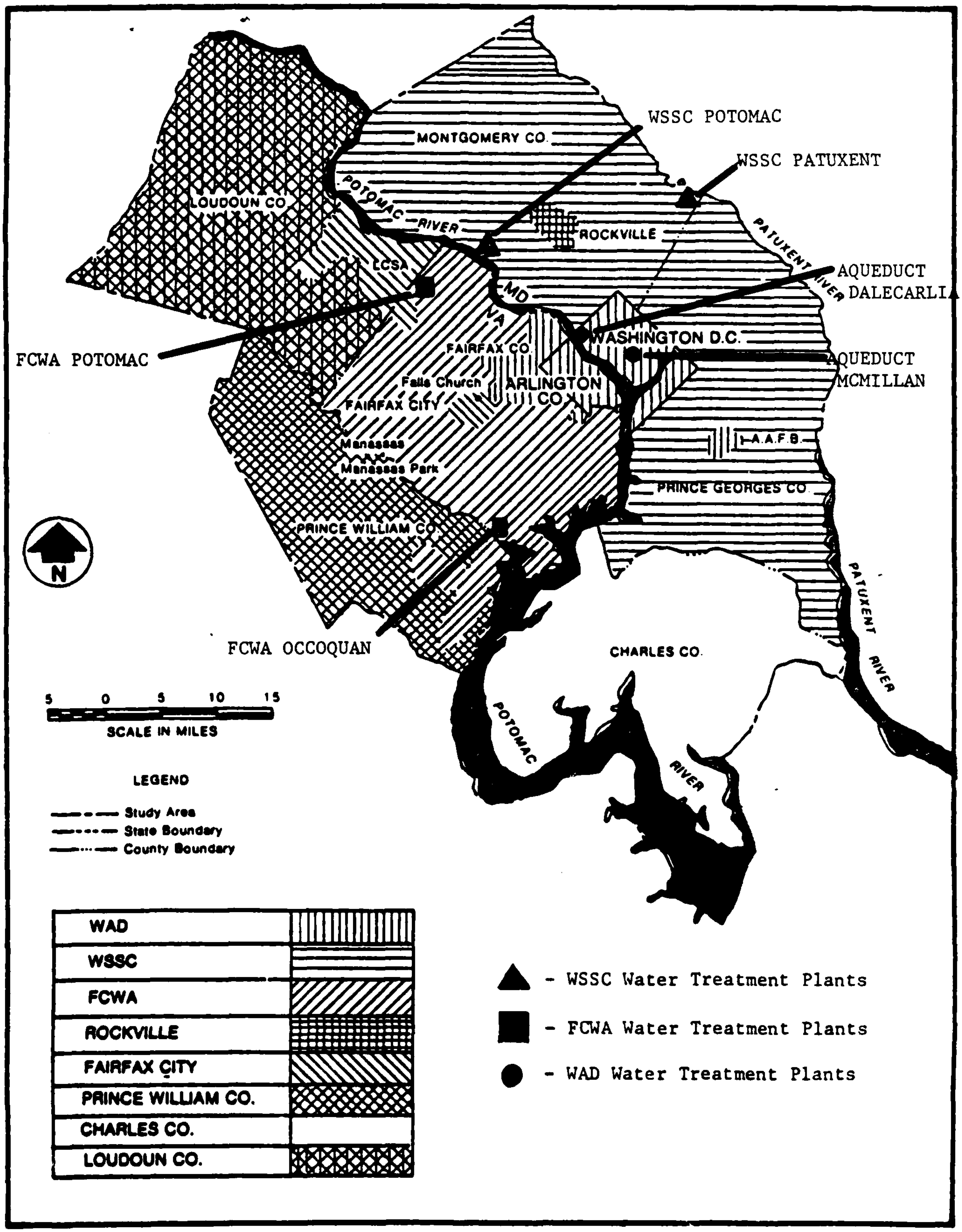


FIGURE G-9

MAJOR WATER TREATMENT PLANTS



Air quality may possibly be affected through the formation of aerosols from spray systems and through odors. With aerosols, the primary concern is with the transmission of pathogens. Odors are caused principally by anaerobic conditions at the site. The establishment of buffer zones and proper management measures (i.e., examination of wind velocities before spraying), should minimize any impacts to the surrounding areas.

The effects of land application systems on the socio-economic aspects of a community include: effects on open spaces, community growth, and changes in local economy. The land application system should be evaluated from an aesthetic point of view with respect to the creation or destruction of greenbelts and open spaces. Proper planning and design can minimize the disruption to the local scenic character and can often enhance the surrounding landscape. The effects of a system may either stimulate or discourage growth of a community. Improved wastewater treatment service may allow for new construction in the service area; however, such growth may tax other community services. The land treatment system may discourage growth by the elimination of land from further development. The effects that a system will have on community growth are related to how the system will affect the local economy. One direct benefit of a land application system is that it reduces the cost of tertiary treatment achieved through other AWT techniques. There also could be changes to land values and tax revenues along with indirect affects on the construction industry and public services.

A final concern in determining the potential of land application are the public health constraints. In many cases, state health regulations serve to protect against many of the effects. However, potential problems include (1) contamination of ground water and surface water, (2) contamination of crops, and (3) and increase in insects and rodents. The effects on ground water and surface water were discussed in the previous section. The effect of effluent on crops is largely dependent on the types of crops and the purposes for which the crops are to be used. Because of the possibility of contamination from pathogens in the wastewater, the control of insects and rodents is of extreme importance. Control of pests can usually be accomplished by conventional methods. Mosquitoes are a special problem because they will propagate in water standing for only a few days. Elimination of standing water and sufficient drying periods between applications are the most effective control methods.

In summary, public acceptability of land application systems will largely depend on the impacts that are expected to occur. The impacts will vary with the type of system selected, the location, and the management techniques that are used. Past experience suggests there is a general reluctance on the part of the public to accept land application measures as a method of treating wastes. It is likely that multiple use with recovery for water supply would be even more strenuously opposed.

CONCLUSIONS

Based on the previous analysis several major conclusions can be made regarding the feasibility of a land application/water supply recovery system for the MWA:

1. Land application by nature is land intensive and requires vast amounts of acreage to recover enough water to appreciably augment Potomac River flows during drought periods. Comparative volumes of water can be secured from reservoir sites occupying land areas smaller by an order of magnitude.

2. Because of the location of sizeable existing treatment facilities and the location of potential land areas for application with respect to water supply intakes, a concern arises as to how to get large volumes to sizeable areas, and then to a point safely above the Potomac River intakes. This concern can be translated to increased costs of transmission, pumping, and land to satisfy all the requirements.

3. Because of limiting climatic and soil conditions, a land application recovery system would be used only on a seasonal basis. Therefore, its use as a substitute for additional treatment is questionable. Furthermore, it is unlikely that large enough areas with uniform soil, land use, and drainage conditions would be available to accommodate a large system within the MWA.

4. There is general public rejection regarding land application as a means of waste disposal, particularly in urban areas. A combined purpose for water supply would probably be even less well received by the public, especially in view of the limited use of such systems on a large scale.

5. Although there are many arguments against land application from an environmental and social impact viewpoint, these impacts can be substantially mitigated through proper management. Public understanding and acceptance of mitigation procedures are vital for implementation.

Based on these conclusions, it is apparent that on a large scale, a land application/water supply system is not feasible in the MWA. Although land application sites might be useful on a limited basis to produce water for non-potable uses, these uses are considered minor and would not appreciably change the overall water supply picture for the region in the future. On this basis, then, land application was dropped from further consideration as a long-range program following preliminary investigations.

WASTEWATER REUSE

The argument for municipal and industrial wastewater reuse is gradually gaining support in the United States today. The concept of wastewater reuse solves two previously separate problems - water supply procurement and wastewater disposal. As water demand in the United States increases, the costs of developing new "fresh" water supplies are increasing. For many regions, the development of traditional water supply sources is reaching the limits of the natural resource, thus calling for more imaginative use of our water resources. Water supply deficits are not restricted to the well known arid regions of the Southwest and California; the more humid northeast corridor with its large urban populations is having to face the hardships of water supply shortages as well.

Concomitantly, the urban areas are dealing with the burdensome task of municipal wastewater disposal. As the metropolitan populations have grown, the volume of wastewater has increased, the level of pollutants has multiplied, and the problem of disposal has worsened. The awakening of the American public and Congress to inherent dangers of unregulated wastewater disposal has led to the passage of environmental legislation during the past decade which placed severe restrictions on wastewater effluent. Thus, by law, municipal and industrial wastewater dischargers are required to either treat their waste waters to a very high degree at enormous costs, or find alternative methods of disposal in lieu of direct surface or groundwater discharge. The expense of advanced treatment facilities has prompted local officials to evaluate more unconventional methods of wastewater disposal.

Consequently, it is likely that wastewater reuse, which takes wastewater and processes it into usable water supplies, will become a feasible solution to the problems of both fresh water supply development and wastewater disposal. In addition, in the future, due to effluent limitations imposed by the U.S. Environmental Protection Agency, much of the treated wastewater may be of as high, or higher, quality than some of the current supply of "fresh" water. Already, sewage effluent constitutes an estimated one percent of municipal and industrial water supplies in the United States and in some cities this figure is as great as 20 percent. Generally, this effluent usage is a result of upstream discharge into surface waters.

Regardless of the obvious technical merits of wastewater reuse, its acceptability is dependent upon the public's clear understanding of the factors involved, the system cost-effectiveness, and a fail-safe monitoring of pollutant levels to avoid potential health risks.

TYPES OF WASTEWATER REUSE

Wastewater reuse strategies are classified as planned or unplanned, direct or indirect, and potable or nonpotable uses. Planned reuse refers to wastewater that is collected, treated, and intentionally provided for additional uses. When water is withdrawn from a surface water supply which has received sewage effluent earlier without the express purpose of augmenting the surface supply, it is called unplanned wastewater reuse. Currently, most municipal wastewater reuse is of the unplanned type, resulting from upstream effluent discharges. For this planning study, discussion has been limited to planned wastewater reuse as a water supply alternative. For planned wastewater reuse, there are two methods of distribution - direct and indirect. Direct reuse is the transmission of wastewater from collection systems or treatment facilities immediately to additional uses. Direct wastewater reuse is used for irrigation systems, industrial processing, and power plant cooling operations. Indirect wastewater reuse utilizes an intervening water system to act as a buffer and storage mechanism between wastewater application and additional uses. Groundwater aquifer recharge and upstream flow augmentation with sewage effluent are currently planned indirect wastewater reuses.

The level of effluent treatment will directly affect the intended reuses of the wastewater. For study purposes, the water quality of the effluent can be divided into potable and nonpotable levels. To reach the level of potability, most wastewaters will require additional advanced wastewater treatment (AWT) beyond secondary processes - an expensive proposition. Potable wastewater can be used for all municipal purposes (drinking, bathing, cooking, and laundry) and most industrial purposes. Some food processing operations may require even more advanced treatment, for specific constituent removal, beyond drinking water standards. Due to the costly advanced treatment processes required for potable water supplies, most planned reuse of wastewater is for nonpotable purposes. Toilet flushing, agricultural irrigation, some industrial processing, and power plant cooling are suitable nonpotable wastewater reuses.

STRATEGIES FOR WASTEWATER REUSE

Uses of the renovated wastewater reflect the quality of the wastewater, the methods of wastewater distribution, and the water needs of the user area. Several alternative reuse strategies exist, including agricultural, recreational, and navigational schemes.

Wastewater reuse can also be applied to power generation operations, groundwater recharge, upstream flow augmentation, dual distribution systems, and municipal water supply.

Agriculture

Agricultural wastewater reuse represents by far the largest percentage of the current recycled effluent in the United States. Agricultural reuse is particularly important in the southwestern regions of the United States where water is in great demand and in limited supply, and where agriculture represents a significant use of potable water. In lieu of diverting great amounts of potable water, wastewater has been successfully used for irrigation purposes for many years. Due to the high nutrient concentrations in wastewater, particularly nitrogen, phosphorus, and potassium, crop production on wastewater-irrigated lands is higher than lands irrigated by normal municipal water supplies.

Another benefit of effluent irrigation is the heat added to agricultural soils. Secondary effluent temperature rarely falls below 55 degrees F, even in the harshest of winters, and rarely exceeds 70 degrees F in the summer. Thus, the application of wastewater to farmlands will tend to moderate the soil temperature. Experiments in the State of Washington have shown that the crop season could be extended by application of the warm effluent. In addition, wastewater application to agricultural lands builds up the groundwater table below. This resultant aquifer recharge may be useful in a land treatment-water collection system, as discussed earlier.

Agricultural wastewater reuse requires careful management to avoid unnecessary contamination of surface and groundwater supplies. The application of wastewater can be restricted to certain crops based on effluent quality. However, crops for human consumption have utilized this wastewater reuse strategy successfully without harmful health effects. The overriding factor in using agricultural reuse as a scheme is the location of irrigation needs. For most urban areas, agricultural uses do not make a large demand on the municipal water supply sources.

Industry

Many industries generate wastewater with quality characteristics adequate for recyling for further industrial use. Industrial reuse has two benefits: (1) it reduces demands on overburdened water supply sources, and (2) it minimizes the quantity of wastewater that must be treated prior to discharge to a receiving body of water. As treatment requirements and treatment costs increase with more demanding effluent quality goals, any reduction in the wastewater flow requiring ultimate treatment will be advantageous to the industrial water user. Reduction in the industrial demand on the municipal water supply system releases potable water for domestic consumption.

Industrial reuse strategies include recycling of secondary effluent from municipal treatment plants as well as wastewater from the industry's own processing. The Bethlehem Steel plant in Baltimore, Maryland for example, utilizes secondary effluent from the nearby Back River sewage treatment plant for use in its cooling processes. Generally, cooling and condensing operations are the primary uses for renovated wastewater. The petroleum, steel, and paper industries offer the greatest opportunities for wastewater recycling. Many other industries require more stringent pretreatment standards, making wastewater reuse less economical. Currently, wastewater reuse is not

practical for food processing industries since potable water is required for most of their operations. The cost of treating effluent to potable standards normally exceeds the cost of developing available water supplies. As fresh water supply development costs climb, this alternative will become more viable.

Recreation

Reuse of wastewater for recreational purposes is not widely practiced in the United States; however, it does offer limited potential for water supply enhancement. Wastewater irrigation of recreational facilities such as golf courses, is one reuse strategy which would result in more potable water for other consumers. Renovated wastewater has also been used to create recreational lakes for boating and swimming. This strategy appears to have very limited water supply potential.

An undeveloped opportunity for recreational wastewater reuse is instream flow maintenance for fisheries. Utilizing this scheme, a base streamflow could be supplied from treated municipal and industrial effluents. Flow criteria would be determined from minimum stream depth requirements for a viable fishery. The addition of large treated wastewater flows might alter the aquatic environment and resulting type of fishery available for recreation. These changes could be controlled by additional wastewater treatment and monitoring.

Navigation

Navigation has limited opportunities for wastewater reuse. Renovated water can be substituted for natural flows in a navigational lock system to maintain sufficient depth for ship passage. This reuse strategy requires controls to prevent the recycled water from diffusing into and contaminating the fresh water supply at the lock ends. This strategy is restricted to those areas with extensive lock systems.

Power Generation

Cooling operations in power generating plants present possibilities for wastewater reuse. Nuclear power plants require large amounts of water to dissipate waste heat which is generated during the production of energy. During the heat dissipation process, a significant percentage of the cooling water is lost to evaporation. By using renovated wastewater in cooling towers and other cooling mechanisms, the evaporation consumptive loss would remain the same but potable water supplies would be reserved for other uses.

Groundwater Recharge

The injection of treated wastewater effluent into groundwater aquifers is a practicable method of using recycled water indirectly for potable purposes. If the soils and percolation characteristics of the aquifer are suitable and the time interval is of sufficient duration, then the natural processes of filtration can restore the effluent with a minimal health risk. Generally, health regulations require a minimum of high quality secondary treatment and often more advanced wastewater treatment to prevent any contamination of groundwater supplies. Several sewage treatment plants in California

have operated successfully for many years without any deterioration in groundwater quality. The recharging of the aquifer with renovated wastewater allows for greater groundwater withdrawals. The extent of groundwater supply enhancement by aquifer recharge is not well known and is still being researched.

Surface Water Recharge

Planned indirect reuse of wastewater via upstream discharge of treated effluent into surface water supplies is a new twist to an old idea. For years, municipalities dumped sewage, treated or not, into streams which downstream users depended on for water supply. The municipalities ignored any concerns for downstream water quality. However, by allowing for enough time for the natural stream cleansing processes to restore the wastewater, the wastewater can be turned into a water supply source. This can be done by pumping treated effluent to a discharge point significantly upstream of water supply intakes. The distance from discharge to intake is affected by the quality of the wastewater discharge, the minimum dependable streamflow, and the stream water quality and flow characteristics. This strategy has high potential for wastewater reuse in urban areas dependent on surface water sources.

Dual Water Systems

Dual water distribution systems present an interesting concept in wastewater reuse. The essence of the concept is the development of two systems for water distribution: (1) a system containing potable water for drinking, cooking, and other domestic uses which require a high level of treatment and (2) a system with lower quality water for fire protection, toilet flushing, lawn sprinkling, and industrial uses. The quality of recycled water would still be quite high and even better than some sources being used for conventional municipal water supply. Dual systems will have more potential in newly developed areas than in already established urban centers since the cost of modifying the existing distribution facilities in populated areas would be excessive. At this time, there are no known municipal dual distribution systems.

The most direct reuse of wastewater is the use of potable wastewater in municipal water supply systems. At present, there are no municipal systems employing this strategy of wastewater reuse in the United States. But in the 1970's, secondary effluent was returned directly to the water distribution system in Chanute, Kansas, without any known health effects. This strategy for reuse faces many implementation problems. Two of the major problems are public acceptance and maintenance of high quality effluent. A significant educational effort is required to overcome the general aversion of most persons to drinking treated wastewater, regardless of its high quality. A direct potable reuse system must have treatment facilities and monitoring systems which are effectively designed to generate water quality control. Similarly, treatment plant operators must be skilled in the sophisticated production techniques which are employed to maintain quality control. Direct wastewater reuse systems do not have a large margin for error without risking human health. Additionally, to reach the level of potability, AWT processes will be required. The costs of the additional treatment facilities must compete with the expenses of new "fresh" water sources and other reuse strategies if direct potable reuse is to be implemented.

APPLICATIONS FOR THE METROPOLITAN WASHINGTON AREA

Wastewater reuse as a feasible water supply alternative for the MWA encounters problems akin to most urban areas. Urban development has significantly reduced the undeveloped land except in the suburban MWA fringes. Yet, water supply demand and effluent discharges are concentrated at the urban center. Consequently, transmission costs reduce the cost-effectiveness of most wastewater reuse strategies.

Agriculture

In the MWA, agricultural land remains primarily in the outlying areas, particularly Charles, Loudoun, and Prince William Counties. In these areas, crop irrigation draws from irrigation wells that are privately owned, and thus, irrigation does not rely on municipal water supplies which could benefit from an agricultural wastewater reuse strategy. Additionally, if agricultural reuse were practicable for water supply augmentation, irrigation water is such a small fraction of the MWA water supply demand and the effluent transmission distance would be so great that the costs would be prohibitive for a regional reuse scheme. Reuse may be feasible for a small farm community with local water supply problems; however, for the MWA region agricultural wastewater reuse does not appear to be practicable.

Industry

In many urban areas, industrial use is a major water consumer. In the Washington region, the industrial and commercial water use is projected to range from a current level of 49 MGD to 105 MGD in the year 2030, as shown in Table G-10. These figures represent a range of 11 to 14 percent of the total water demand. Of the major industrial users, almost all are food-processing operations which require potable water. In the WSSC area, which has the largest industrial use in the MWA (11 MGD in 1980, and 43 MGD projected for 2030), the large industrial water consumers include Coca-Cola Bottling Company (0.230 MGD), Safeway Dairy (0.175 MGS), Frito-Lay, Inc. (0.156 MGD), Giant Food Milk Plant (0.170 MGD), and Pepsi-Cola Bottling Company (0.128 MGD). Mineral pigments (0.216 MGD) and Rockville Crushed Stone (0.159 MGD) are the only significant non-food processing water users in the WSSC. The limited industrial water use is repeated in the remainder of the metropolitan region. Hence, there is no single industrial user in the MWA which could reuse significant quantities of wastewater as a substitute for publicly supplied water. An industrial reuse scheme would have to involve many small industries which are currently scattered throughout the Washington region. This wastewater reuse strategy has very little potential as a cost-effective approach for water supply in the MWA.

The MWA does not have a significant water-consuming power-generating plant within its defined boundaries nor an extensive navigational fresh water use. Major navigation is restricted to the Potomac Estuary. Consequently, navigational and heat-dissipation wastewater reuses are not feasible alternatives. Also, because the MWA is already extensively developed, dual water systems are highly improbable, as discussed earlier.

Groundwater Recharge

Currently, in Charles and Prince William Counties, approximately 40 percent of the water demand is satisfied by groundwater. It is anticipated that continued growth in these counties will place a greater demand on their groundwater resources. Recharge of groundwater aquifers with wastewater is a potential water supply alternative for these

TABLE G-10

MWA COMMERCIAL/INDUSTRIAL WATER DEMAND
PROJECTIONS-BASELINE CONDITIONS

Year	Commercial/Industrial Demand (MGD)	Total Water Demand	Percent of Total Demand
1976	45	421	11
1980	49	439	11
1990	63	530	12
2000	73	593	12
2010	83	649	13
2020	94	710	13
2030	105	765	14

areas that have and utilize groundwater resources. Two general approaches are injection of wastewater directly into the aquifer and spreading of wastewater to allow for natural filtration through the soil. These approaches were considered in the long-range phase of the study but because of the great degree of uncertainty associated with them, they were not considered to be as feasible as several of the other alternatives.

To begin with, to be considered as a viable alternative, this method of wastewater reuse would have to provide large amounts of water. The only area of sufficient capability for recharge is the Atlantic Coastal Plain. While potential yield estimates of the Coastal Plain aquifers were developed by the U.S. Geological Survey for the Corps of Engineers, there was no determination of the need for, or benefit of, wastewater recharge in the aquifers. The majority of the groundwater resource is in the deep aquifers; up to now, local withdrawals in the study area have been minimal and the new pumping levels simulated by the USGS were at a duration and rate that did not significantly impact the existing resource. This raises another question of whether the aquifers need to be recharged in this fashion at all. Then, the question of which aquifer to recharge has to be addressed. Do you recharge the surface formations or the deep water-abundant aquifers? The availability of large tracts of land is another constraint. There is also a question of potential health problems which may arise especially with a wastewater injection program. Finally, there is the question of whether the appropriate aquifers could easily be tapped and used as a source of supply for the MWA. For these reasons, groundwater recharge was not considered further.

Direct Reuse

An additional wastewater reuse strategy would employ direct potable reuse, in which treated wastewater (of a very high quality) would be transmitted to and utilized directly in the water supply system. This alternative may prove feasible with advances in wastewater treatment engineering. However, until that time, public attitude toward such a scheme will prevent its implementation. Other schemes such as the surface water recharge concept previously developed may have a better possibility for implementation.

Potomac River Recharge

A possible water supply alternative for Potomac River uses is a scheme for discharging highly treated effluent either upstream or downstream of the Washington water supply intakes. This would effectively increase the safe yield of the Potomac River at Washington, D.C., by the amount of the wastewater discharge. Upstream discharge alternatives were originally evaluated in the Northeastern United States Water Supply (NEWS) Study which was completed in 1977. To be suitable for indirect reuse in this manner, the wastewater discharge would require advanced wastewater treatment beyond conventional secondary treatment in order to meet the stringent effluent guidelines imposed by Federal and state agencies.

The NEWS study investigated three sites for AWT effluent discharge. The AWT projects were a Montgomery County AWT plant (future facility), a Fairfax County AWT plant (future facility), and the Blue Plains (existing Washington, D.C., facility) Pumping Station-Pipeline. All three schemes would discharge effluent to the Potomac River near Dickerson, Maryland, which is located 15 miles upstream of the FCWA intake and 28 miles upstream of the Little Falls intake. As presented in the NEWS Report, the costs associated with these schemes were very high (+$200 million).

The Montgomery and Fairfax plants were planned for continuous operations; the Blue Plains discharge would be on an as-needed basis. The Montgomery and Fairfax AWT plants have not gone beyond the conceptual stage and no actions are planned for the future; there is much opposition from local citizens and Federal officials to the expensive treatment facilities. Also, the Maryland Environmental Health Administration (EHA) has not approved the Dickerson site for AWT discharge. EHA is concerned that the effluent discharges might jeopardize the Potomac water supply during low flows. Since no specific effluent discharge criteria exist for drinking water supplies, EHA plans to evaluate any proposal for treated effluent discharge on a case-by-case basis.

MWA Water Supply Study Investigations

Despite the shortcomings surrounding recharge above the MWA water supply intakes, it was felt that the feasibility of such an alternative still merited further study and updating from a long-range viewpoint. Furthermore, a recharge scheme involving a discharge location below the last Potomac River water supply intake at Little Falls was introduced as an alternative to the upstream location.

Figure G-10 depicts the two recharge possibilities. They involve the pumping of 100 to 200 mgd of highly treated effluent from the downstream sewage treatment plant(s) to either a discharge point immediately downstream from the Little Falls intake or eight miles further upstream. These discharges would augment the natural flows in the Potomac on an as-needed basis. The upstream location would directly increase the flow in the river in the vicinity of the Potomac intakes whereas the downstream location could only be used as an "environmental flowby" substitute, thus permitting the Potomac River users to benefit from the corresponding "natural" flow in the river which would otherwise pass to the Estuary unused.

In order to prevent any possible degradation of the water supply, the outfall would have to be located sufficiently downstream from the water supply intakes or a barrier and monitoring system would have to be provided. In all likelihood some form of advanced

wastewater treatment would be required of the effluent although the State of Maryland does not generally object to a discharge downstream from the water supply intakes.

An effluent discharge in the range of 100-200 mgd could be supplied by the Blue Plains plant which is located approximately 13 miles downstream from the Little Falls intake. Blue Plains presently has a discharge in excess of 300 mgd and may be expected to expand over the next fifty years and have a project discharge of nearly 500 mgd. On the Virginia side of the Potomac, the Arlington and Alexandria sewage treatment plants presently release a flow of approximately 60 mgd. The total projected flow of these plants is expected to reach approximately 80 mgd within the planning period. Given the above plants as potential sources, it was decided that a scheme using the Blue Plains plant as a source would be investigated in further detail.

Design and Cost of Potomac River Recharge Alternatives

Two proposals were considered. The first called for pumping the treated water upstream from Blue Plains to Little Falls, a distance of approximately 13 miles. The second alternative was very similiar, the only appreciable difference being that the water was pumped an additional eight miles upstream, to Great Falls. Two flows, 100 MGD and 200 MGD, were investigated for both alternatives.

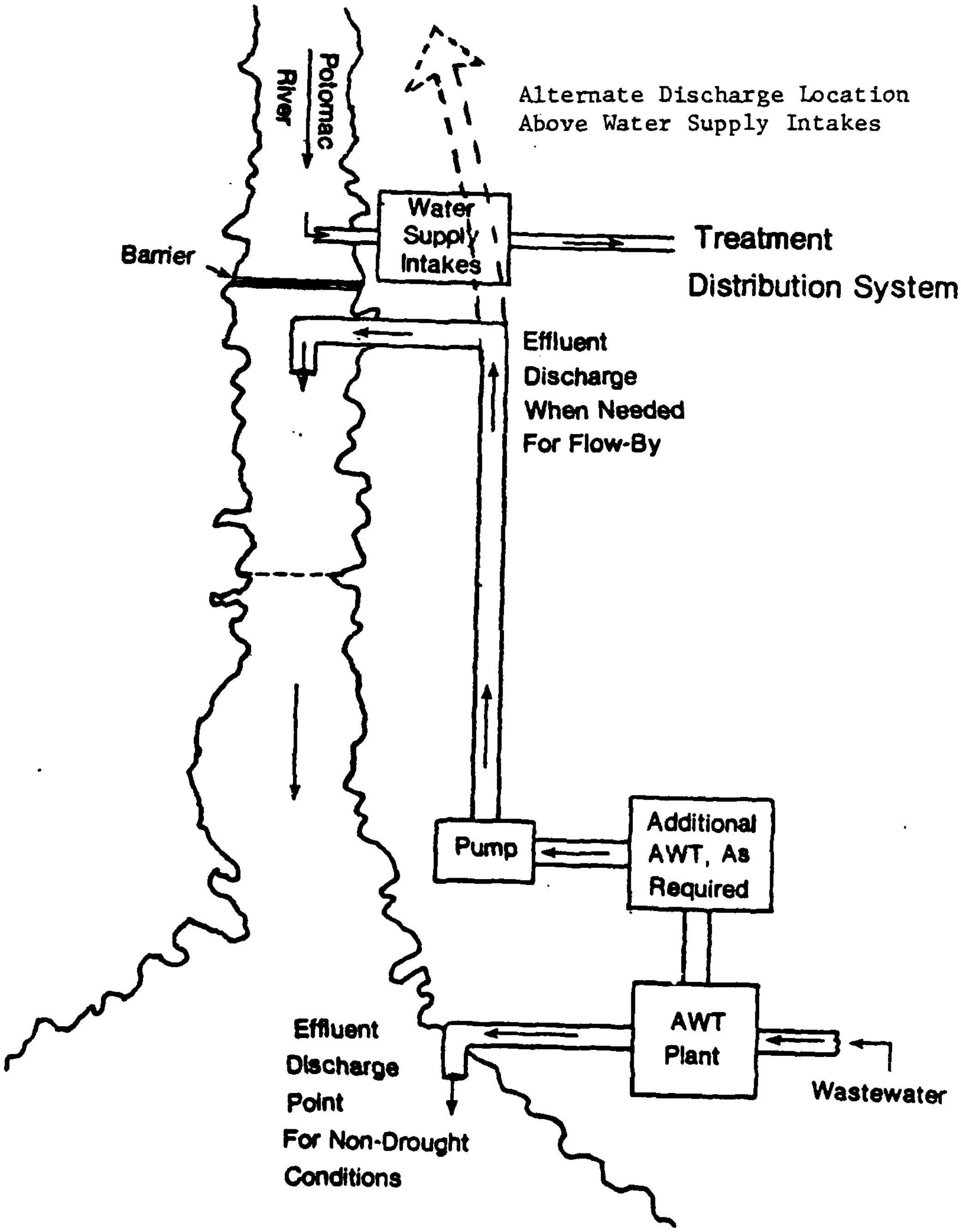
Costs for both the pipeline and the associated pump station(s) were estimated using the Methodology for Area-wide Planning Studies (MAPS) computer program. The MAPS program was developed by the U.S. Army Corps of Engineers' Waterways Experiment Station. It is a generalized planning tool for evaluating water resource alternatives. As such, it provides preliminary design and cost estimates for comparison purposes.

The costs in the MAPS program account for many of the independent variables that normally impact on costs. Consequently, the results are usually more accurate than generalized cost curves available in literature, which are a function of only one or two variables. The MAPS program takes user-specified, engineering design data and applies several cost functions to determine various construction costs and operation and maintenance costs. Itemized construction, total construction, overhead, land, total capital, amortized capital, operation and maintenance, labor, material and supply, power, total operation and maintenance, and average annual costs are provided by the program. All costs are calculated by the program except for the land cost which is input directly by the user. The costs are based on a set of economic data (user-specified) which reflect October 1981 economic conditions. The cost estimates, however, do not reflect site specific design considerations.

The economic data assumed for this study include an Engineering News Record (ENR) Construction Cost Index of 3672 and a power cost of 4.0 cents per kilowatt-hour. This value reflects the cost of electricity for commercial properties serviced by the Virginia Electric Power Company (VEPCO). For the amortization calculations, the Federal Water Supply interest rate of 7.625 percent was assumed along with a 50-year payback period.

FIGURE G-10

REPRESENTATION OF FLOWBY REPLACEMENT SCHEME



The MAPS program uses the economic data and information describing the pipe and pump station to perform a cost analysis. It integrates the data from these components and, for a given flow, lists a series of possible pipe sizes and the associated number of pump stations needed. It also computes some characteristics of the system (in-pipe velocity, system losses and required pump head) along with capital, O&M and annual costs of both the pipe and pump stations.

Much of the input data for the pipes came from USGS topographic maps. They include the length of pipe, the initial elevation, the peak elevation, and the final elevation of both pipe routes. In addition, the number and type of pipe appurtenances were estimated from the physical layout of the routes. The possible appurtenances included gate valves, standard elbows, medium elbows and long sweep elbows. The percent of terrain type for both alternates was also estimated for the cost program. This information is listed in Table G-10A. The last identifying item was the cost of right of way for each pipe. This value was calculated from the length of pipe and a $1 million per mile estimate of the right of way, based on land costs developed by the Corps of Engineers for the central MWA corridor.

Prestressed concrete cylinder pipe was chosen for the pipe material; this was consistent with similarly sized raw and finished water interconnections in the MWA. The pipes were assumed to be laid under dry soil conditions with no rock excavation required. They would be laid in a rectangular trench with a depth of 3 feet greater and a width of 1.5 feet greater than the pipe diameter. No concrete cradle was assumed.

The MAPS program designed and priced the pump facilities according to the following assumptions. First, an efficiency of 80 percent and a downtime of 58 percent were assumed. Downtime is that time in which the pumps are not working. It was estimated that the pumps would operate only 5 months during a drought year. Other assumptions included that a single station could provide no more than 1,000 feet of head, would not have a wet well, but would have an electrical switchyard. A switchyard is often required to provide necessary voltage for larger pumps.

From the range of pipelines and corresponding costs generated by the MAPS program, an optimum pipe size was selected for each route and flow rate. These are shown in Table G-10B. Both design and economic considerations affected this selection. From a design standpoint, in-pipe velocities should not exceed a maximum of 10 feet per second (FPS) and design velocities are commonly 4 to 6 FPS. Velocities exceeding 10 FPS can cause erosion of pipe material or high pressure differentials (i.e. water hammer). From an economic viewpoint, the capital, annual and O&M costs must all be taken into consideration. Capital costs increase with increasing pipe size, as one would expect, due to the additional excavation needed. On the other hand, O&M cost decrease with increasing pipe size. This is because smaller pipes have a greater friction loss than larger pipes, and require more mechanical energy to move a given volume of water.

Impacts of Recharge Alternatives

Given the approximate pipe diameters which were chosen, consideration was then directed to the pipeline route between Blue Plains and the discharge points. After only a cursory examination of the area to be traversed by this pipeline it became evident that the environmental and cultural impacts of such a project would be extremely severe.

TABLE G-10A

DESCRIPTION OF PIPE SEGMENTS

ITEM	BLUE PLAINS TO LITTLE FALLS	BLUE PLAINS TO GREAT FALLS
Length of Pipe	68200 ft	11000 ft
Initial Elevation	10 ft	10 ft
Peak Elevation	250 ft	380 ft
Final Elevation	30 ft	140 ft
Gate Valves	3	8
Standard Elbows	3	5
Medium Elbows	6	9
Long Sweep Elbows	11	14
Terrain Type		
Sparse Residential	20 %	40 %
Dense Residential	30 %	30 %
Commercial	50 %	30 %

TABLE G-10B

WASTEWATER REUSE SCHEME COST SUMMARY

	Blue Plains to Little Falls		Blue Plains to Great Falls	
	100 MGD	200 MGD	100 MGD	200 MGD
Pipe Diameter (inches)	66	96	72	108
Length (miles)	12.9	12.9	20.8	20.8
Pipeline Capital Cost $	40,900,000	70,000,000	71,400,000	131,000,000
Pump Station Cost $	5,100,000	8,630,000	5,830,000	9,940,000
Total Capital Cost $	46,000,000	78,630,000	77,230,000	140,940,000
O&M Total Cost ($/Yr)	527,100	730,000	853,000	1,304,000
Average Annual Cost ($/Yr)	4,130,000	6,880,000	6,890,000	12,300,000
Velocity (Feet per second)	6.5	6.2	5.5	4.9
Pump O&M ($/Yr)	457,000	614,000	732,000	1,090,000
Pipe O&M ($/Yr)	70,100	116,000	121,000	214,000

*Costs were based on October 1981 values, and an interest rate of 7.625 percent. Total O&M cost include pipe O&M plus pump station O&M.

Construction of a pipeline of this size would be expensive even under optimum conditions. Furthermore, the design and construction practices that would be required through large park areas which have high natural significance would likely make a project of this type economically impractical and socially disruptive.

While not possible at this time, future consideration should be given to a flowby scheme in the event a major (flows in excess of 100 mgd) wastewater treatment facility is ever constructed in the northern portion of the MWA. If, for example, a major plant was constructed in Montgomery County it may be feasible to direct the effluent from that plant to a Potomac outfall downstream from the Little Falls intake. The economic, environmental and social impacts of such a proposal might be less severe than those noted for a Blue Plains related scheme.

Further consideration should also be given to the type of additional treatment required. Admittedly, the type of additional treatment required is a matter of speculation at this point. A more comprehensive water quality analysis to include both numerical and physical modeling would be required to better understand both the hydrodynamics and the water quality implications of the proposed scheme. Given this information the level of additional treatment required, if any, could be selected.

A major concern for the Little Falls discharge point would be the potential conflict this outfall might create with respect to the Washington Aqueduct Emergency Estuary Pumping Station. The operation of this intake, designed for use only during emergency conditions, is contingent upon a safe and treatable supply in the uppermost portion of the estuary. Wastewater discharges from Blue Plains in the vicinity of this intake would have to be critically evaluated to determine if, in fact, the emergency pumping station could be safely utilized.

The Potomac River system is not the only water system which would be feasible for upstream effluent discharges. The Occoquan and Patuxent River reservoirs could also be augmented by wastewater reuse, although the available wastewater flows would not be as significant as the Blue Plains discharge. However, the same problems of Potomac discharges would still remain: (1) the location of discharge, in order to retain the potable water supply in the system; (2) the required quality of the effluent discharge; (3) public acceptance; and (4) cost-effectiveness.

CONCLUSIONS

Presently, wastewater reuse is not widely practiced. Its economic efficiency will be one of the primary factors in determining the future of wastewater reuse. Wastewater reuse projects will incur additional costs for advanced wastewater treatment, (i.e., costs for special equipment, process chemicals, and energy consumption). The conveyance of effluent to the reuse site, monitoring systems, etc., will add to the expense of a wastewater reuse strategy. The ultimate cost-effectiveness of the reuse strategy will be contingent upon the costs of alternative water supply sources in the future.

In addition to the economic aspects, the feasibility of wastewater reuse implementation depends on the satisfactory resolution of several key issues:

1. public acceptance.

2. public health concepts -- potential contamination of water supply sources and the build-up of pollutants to toxic levels.

3. institutional acceptance — environmental, wildlife, and health agencies at Federal, state, and local levels.

4. economic complications - cost distribution among water and wastewater agencies, rate structures for freshwater versus recycled wastewater, etc. The solutions to these problems may prove to be very difficult; however, advances in technology and the lack of alternative water supply sources could be the justification for wastewater reuse as a water supply answer in the future.

For the MWA, various reuse strategies were evaluated on a conceptual basis. Of the measures considered recharge of the Potomac recharge appeared to hold most promise and was considered further for long-range formulation.

WATER PRICING

INTRODUCTION

The legislation which authorized the MWA Water Supply Study included several stipulations regarding the conduct of the study. Two of these stipulations are addressed in the discussions of wastewater reclamation and water conservation in other sections of this appendix. A third condition that was to be assessed during the course of the study is the effect water pricing policies may have on the future demand for water. That is to say, would adjustments in the price of water charged to consumers be an effective way of reducing the overall demand for water in the MWA.

To comply with the intent of the authorizing legislation, the role of water pricing in water supply planning for the MWA was examined during the analysis of long-range alternatives. In September 1980, a contract was initiated with the firm of Jack Faucett Associates to develop price data and analyze the effects of pricing policies on water demand in the MWA. The general purposes of this study were:

1) to develop concepts for better pricing and for measuring impacts of price changes;

2) to determine the effectiveness of prices and pricing (rate) strategies in reducing demand,

3) to evaluate impacts of alternative pricing strategies, and

4) to determine the feasibility of implementing various pricing strategies; that is identify practical and political constraints.

The consultant's analysis was completed in June 1982 and the consultant's final report is included as Annex G-II to this appendix. The intent of this section is to summarize the consultant's work effort and to highlight the findings and conclusions.

FORMAT OF PRICING STUDY

As a result of the early-action analysis documented in the August 1979 Progress Report, Plans for Choice were developed only for the Potomac water users rather than for the entire MWA. This was done because the early-action alternatives examined had little or no applicability to the outlying service areas while their potential for solving the Potomac users' water supply problem was great. The general approach taken in the water pricing analysis was compatible with the approach followed in the early-action effort. Two general areas comprising the MWA were examined in the water pricing analysis albeit to somewhat differing degrees, but examined nonetheless. The conduct of the MWA water pricing study as an analysis of Potomac River users and one of outlying service areas was pursued in this manner for several reasons:

1) because several water suppliers rely on a raw water source common to them all, it was felt that this interdependence should be maintained in the analysis,

2) the existence of many smaller systems in the outlying service areas, each relatively independent in its own right,

3) anticipated problems with data collection especially in the outlying service areas,

4) at the time of contract commencement, there existed potential for the development and adoption of a regional water supply strategy by the Potomac River users; consequently, an analysis of pricing policies in a Potomac River context could be of special interest if regional water supply strategies were to be implemented.

The scope of work contained several tasks which were designed to provide indication of the degree to which pricing policies would reduce the amount of demand growth to be faced by water suppliers. The tasks included the consideration of water supply/wastewater relationships, the development of demand elasticity estimates, the consideration of inflationary effects on future costs, and the development of a water pricing strategy. However, because of the dynamic nature of water supply planning in the MWA during the past several years, the direction of the pricing analysis was altered. This will be explained later in this section.

ISSUES AND CONCERNS

Similar to many other alternatives, water pricing strategies have their proponents and their opponents. Many environmental interests view water pricing as being preferrable to structural alternatives because of the minimization of environmental impacts. Some environmentalists and consumer interests hold the view that growth-related connection charges should not be passed to existing water users. In this way, the higher costs of new facilities would be borne wholly by those causing the growth (and higher costs) and, therefore, environmental costs of expansion would be better reflected. Consumer advocates may feel that pricing for conservation has merit but that the imposition of water pricing may not be equitably distributed. Utility planners are required to provide adequate service, and since both the responsiveness of water demand to price changes and inflationary effects on construction costs are uncertain, there is an uneasiness associated with water pricing. The economist and the rate analyst understand the basic flaws in many current rate structures. The cost of water during peak use periods is underpriced and may encourage waste thus contributing to demand for new capacity. Economists believe pricing should focus on the timing of demand use rather than (as the rate analyst believes) on the amount of demand. Peak period rates should be used to distribute the high cost of peak capacity to those who demand peak period water.

All of the above concerns address basically the same objectives - efficiency and equity; that is, making the best use of resources and distributing cost so that everyone pays their fair share - no more and no less. The theoretically "best" way to accomplish these objectives is through the use of peak period marginal cost pricing. This approach to pricing represents the opportunity cost of the resources used to provide water in peak periods. The "marginal cost" is the cost to produce the last unit of a good at the peak period level of output. It was this concept of marginal cost peak period pricing that was used as the evaluative standard in the analysis of pricing in the MWA.

METHODOLOGY OF PRICING STUDY

Approximately fifty percent of the effort expended during the course of the pricing study was directed toward the development of a data base. Twenty-two individual water/wastewater billing agencies were analyzed based on the existing data. Table G-11

presents these agencies categorized as Potomac users or outlying service area utilities. Because water billing is influenced by wastewater use and billing, it was necessary that wastewater costs also be collected and analyzed jointly. This proved to be a very intensive task due to the complexity of the water/wastewater infrastructure. Figure G-11 is a representation of the existing network.

Subsequent to collecting this cost information, disaggregation and reclassification of the data occurred to permit analysis of costs in terms of peak and non-peak use. This cost categorization, presented in Table G-12, was necessary for proper development and analysis of a rate structure based on marginal cost peak period pricing. A three-part rate structure was designed which included a fixed charge, a commodity charge, and a peak use charge. The fixed cost portion reflects costs such as billing costs that do not vary with the quantity of water or sewer flows. The commodity charge portion of this rate structure reflects capacity costs (and related O&M costs) incurred to meet average day demands. The peak season surcharge represents the portion of capacity (and related O&M costs) used during the peak period.

Along with development of this three-part rate structure, future water supply costs were estimated. These costs were then incorporated into the utilities' existing rate structure and the one just described to arrive at estimates of future water costs in cents per thousand gallons. The results of this effort as influenced by recent developments provided the rationale for the several findings of the pricing study.

RECENT WATER SUPPLY ACTIVITIES

Shortly after initiation of the water pricing analysis, efforts to develop and institute a coordinated approach to water supply planning intensified. The Washington Metropolitan Water Supply Task Force (discussed in detail in the Main Report) had determined that with coordinated use of the Potomac River and existing reservoirs, only the Little Seneca Lake project needed to be built to satisfy area water demands to the year 2030. Stated differently, if such agreements were negotiated, no costs, other than Little Seneca project costs, would be incurred for additional capacity (peak or otherwise) during the planning period. This supply management technique could greatly expand the capacity of existing supply projects at relatively little cost. Concomitant with this development was the June 1981 acceptance of a Potomac River flowby value by the signatories to the Potomac Low Flow Allocaton Agreement. The accepted minimum value of 100 mgd further contributed to the realization that structural water supply alternatives would not be constructed in the future.

FINDINGS AND CONDITIONALS

As demand has exceeded the capacity of nearby and easily developed water sources, the cost (including the environmental cost) of providing new water supply capacity for urban areas has escalated significantly. Pricing policy has become a potentially effective means of controlling the rate of demand growth and thus economizing on capacity costs.

TABLE G-11

WATER/WASTEWATER BILLING AGENCIES

POTOMAC RIVER UTILITIES

District of Columbia/Washington Aqueduct Division	City of Rockville
Washington Suburban Sanitary Commission	Arlington County
Fairfax County	Town of Vienna
City of Alexandria	Dale City
City of Falls Church	Occoquan Woodbridge/Dumfries Triangle Sanitary District

OUTLYING SERVICE AREA UTILITIES

Loudoun County Sanitation Authority	Town of Quantico
Town of Leesburg	Greater Manassas Sanitary District
City of Fairfax	City of Bowie
Town of Herndon	Town of LaPlata
City of Manassas	Town of Indian Head
City of Manassas Park	Charles County

FIGURE G-11

MWA WATER AND WASTEWATER TRANSMISSION

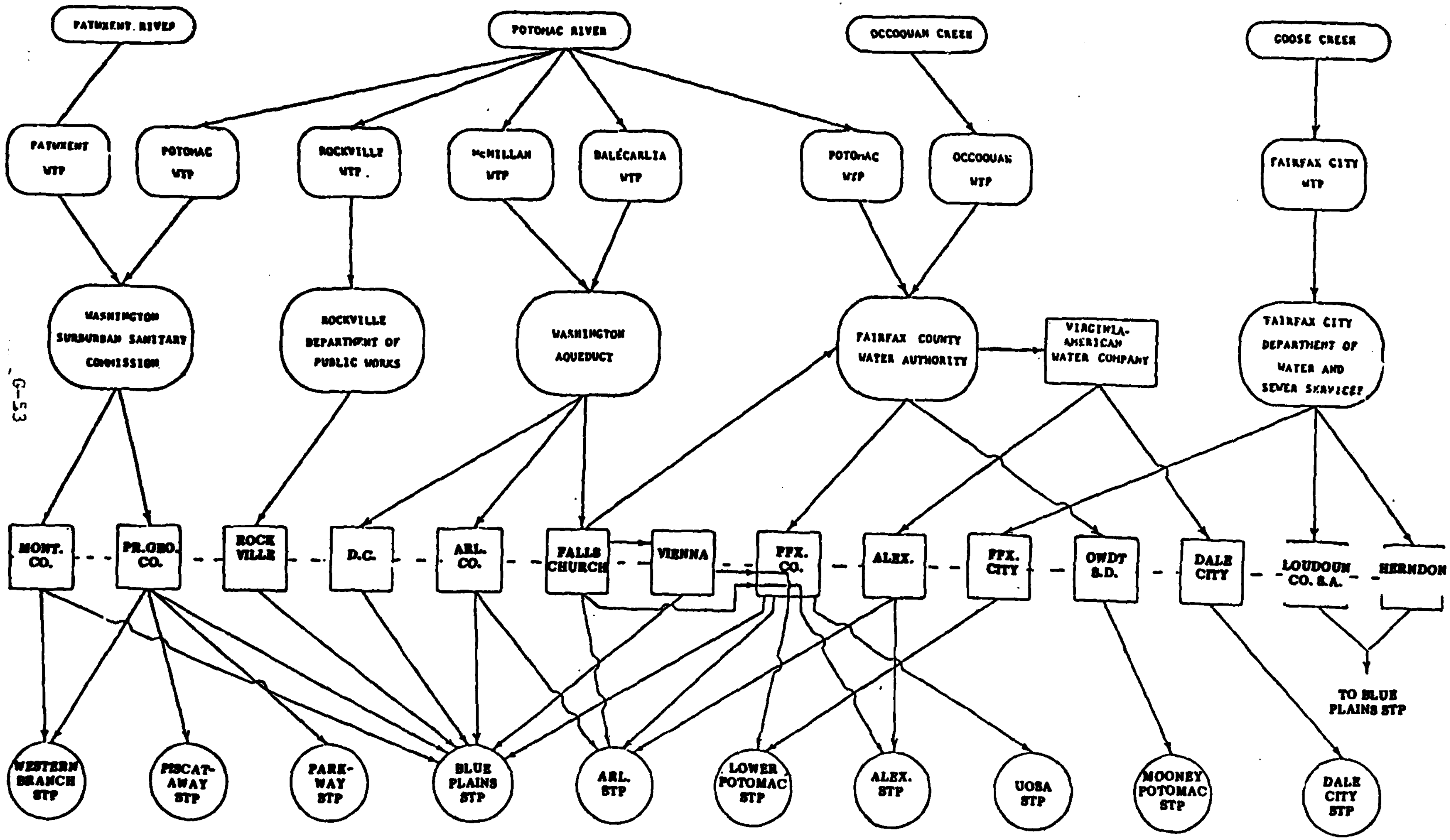


TABLE G-12

COST CATEGORIES DEVELOPED FOR
WATER PRICING ANALYSIS

CATEGORIES	DESCRIPTIONS
Water Short-Run Marginal Cost	
Water Source O&M (flow)	- example: raw water pumping
Water Treatment O&M (flow)	- example: chemicals
Water Distribution O&M (flow)	- example: finished water pumping
Water Long-Run Marginal Cost	
Water Source Capacity	- new supply projects
Water Source O&M (capacity)	- example: maintenance crew for a new reservoir
Water Treatment Capacity	- new treatment plant capacity
Water Treatment O&M (capacity)	- example: labor to staff new plant
Water Transmission Capacity	- new transmission mains
Water Transmission O&M (capacity)	- example: line maintenance for new main
Sewer Short-Run Marginal Cost	
Wastewater Treatment O&M (flow)	- example: chemicals
Wastewater Collection O&M (flow)	- example: pumping
Sewer Long-Run Marginal Cost	
Wastewater Treatment Capacity	- new wastewater treatment plant capacity
Wastewater Treatment O&M (capacity)	- example: labor to staff new plant
Wastewater Collection Capacity	- new sewage collection mains
Wastewater Collection O&M (capacity)	- line maintenance for new mains
Fixed Costs	
Administration	- example: general administration, billing, etc.
Water Distribution Capacity	- unretired costs of existing water distribution system
Water Distribution O&M (fixed)	- line maintenance on fixed distribution system
Wastewater Collection (capacity)	- unretired costs of existing wastewater collection system
Wastewater Collecton O&M (fixed)	- line maintenance on fixed collection system

NOTES:

O&M (flow) = O&M costs that are a function of flow
O&M (capacity) = O&M costs that are a function of new capacity
O&M (fixed) = O&M costs that are a function of fixed capacity

In theory, a marginal cost peak period rate structure will produce higher prices reflecting the high cost of new capacity and therefore result in a more economical rate of demand growth. Further, the rate of growth produced by a marginal cost peak period rate structure is the theoretically optimal rate of growth from a benefit/cost viewpoint (provided all relevant benefits and costs are accounted for). Prices higher than marginal cost peak period rates produce less than optimal levels of consumption; more is lost in foregone benefits of consumption than is gained in foregone costs of new capacity.

Only a few studies have attempted to apply this theory to practical situations in the water industry. The findings of these studies indicate that there are two major limitations to practical application: (1) marginal cost peak period pricing tends to work better in the west where water resources are more scarce and expensive to develop, and (2) the effectiveness is diminished if fixed costs, which cannot be included in marginal cost rates, are a high proportion of total costs.

In the MWA water pricing analysis, both of these limitations were found to be important. New strategies for regional cooperation in supply management have made great economies of scale available to the Potomac dependent utilities. Through coordinated operation of the existing supply facilities in the region, the utilities have expanded the potential of existing capacity, reduced the unit cost, and postponed the need for new capacity.

It was also found that the proportion of fixed costs to total costs in utilities within the region is relatively high further decreasing the potential effectiveness of marginal cost peak period pricing. This is especially evident because both water and sewer costs were covered in the study and the combined fixed investment represented by the distribution and collection systems is substantial. Yet, sewer costs must be included because sewer rates are based on water consumption and many consumers, receiving a combined billing, regard both services as a single commodity.

As a result of these limitations, it was determined that a marginal cost peak period rate structure would not produce a reduction in the rate of demand growth in the Metropolitan Washington Area in the near future (not before the year 2000). The marginal cost peak period rate would be less than the price charged under current rate structures because of the high fixed cost and the reduced cost of new capacity made possible by supply management.

This major finding is conditioned by the study assumptions especially as they relate to order of magnitude, error involved in cost estimates, and exclusion of intangible or external costs from consideration. For this reason, it is one thing to say that marginal cost pricing will not work now and quite another to say that it will be worthwhile later. Factors addressed in the analysis which may change are:

1) the amount of demand reduction due to conservation may be more or less than that reflected by Water Conservation Scenario Three,

2) the amount of flowby required to sustain water quality may be greater than the present amount of 100 mgd,

3) factors affecting cost forecasts could change (though an effort was made to err on the high side),

4) an additional allowance for intangible social costs (such as environmental costs of new water supply capacity) may be warranted for items not included in study estimates.

In summary, given the above conditions, the unusual economics of scale related to the new capacity made possible by regional supply management have made marginal cost peak period pricing an ineffective tool for demand management in the short run. Over the longer term, it is likely that either changes in the assumed conditions or continued demand growth will produce a situation in which costs rise fast enough to justify the use of marginal cost pricing. Furthermore, the move towards regional cooperation engendered by the attraction of supply management has produced new institutional arrangements that have the potential to assure that a transition to better pricing policies will be forthcoming as conditions change.

In designing an institutional approach to sharing the cost of regional cooperation in supply management, the Potomac dependent utilities have agreed to share the cost of future capacity in proportion to their respective shares of the growth in regional peak period demand. This mechanism can act as a built-in device that will provide strong incentives to utilities to move towards either marginal cost peak period pricing or a similar rate design when conditions warrant it.

The following recommendations are made to enable utilities to be in a better position to recognize and take advantage of pricing opportunities in the future:

1) Better documentation of cost data according to "avoidable cost" categories would permit more accurate assessment of pricing policies.

2) More extensive forecasting of future costs would improve the quality of pricing analysis and permit utilities to view the future in terms of their own inflation and interest rate assumptions.

3) Greater study of options for modifying billing practices to coincide with peak periods would refine the ability to design peak period pricing strategies.

4) More extensive economic research and data collection on demand elasticity should be performed to improve the ability to forecast the effects of pricing policies.

CONSERVATION AND DEMAND REDUCTION

INTRODUCTION

To an increasing degree, the use of the term "conservation" or the phrase "conservation and demand reduction" is occurring in discussions of the interactive relationship between the demand for water and the availability of supply. Stated in a simple manner, conservation and demand reduction is the means of decreasing the use of water while more efficiently utilizing available supplies. Water conservation can also be defined as any beneficial reduction in water use or water losses. Situations of drought and shortage in various sections of the United States have demonstrated the viability, acceptability, and effectiveness of the practice of conserving water. With the use of water, as well as the cost of supplying it, expected to increase, the concept of water conservation is being looked to not only as a short-term emergency solution, but also as a means of decreasing everyday use of this valuable and necessary resource.

Within the Metropolitan Washington Area, this concept has attracted increasing attention from all areas of concern: citizens, special interest groups, water utilities, and water resources planners. This discussion of conservation and demand reduction is oriented toward a presentation of the concept as one of the several components considered by the MWA Water Supply Study. This section will present results of the work effort undertaken for the Corps of Engineers by Camp, Dresser, and McKee (CDM) to formulate specific water conservation and demand reduction programs for the MWA and simulate their effectiveness.

This section will briefly trace developments resulting in the increased emphasis on water conservation and demand reduction in the MWA. Then, the water use analysis undertaken by CDM will be summarized by water service area and the techniques considered as water-saving measures will be described. This will then be followed by a discussion of the water conservation scenarios developed during the study. This section will conclude with a discussion of the estimated costs of scenario implementation over the course of the period of analysis.

WATER CONSERVATION IN THE METROPOLITAN WASHINGTON AREA

In October 1965, Congress enacted Public Law 89-298 which, through Title 1, authorized the Northeastern United States Water Suppy (NEWS) Study to examine various alternatives for addressing the long-range water requirements of the northeastern areas of the country. The MWA segment of the NEWS Study recognized that there was evidence of a growing interest in developing and implementing conservation measures in the region. In response to this tendency toward increased use of water-saving devices, the NEWS Study examined several means of reducing water use in the MWA including pricing, water-saving devices, and temporary use restrictions. No specific conservation plans were developed, but the NEWS Study water demand projections were reduced by one million gallons of water per day per year to reflect anticipated effects of conservation.

In response to the findings of the NEWS Study, Congress, through Section 85 of Public Law 93-251, authorized a detailed analysis of the water supply problem in the Metropolitan Washington Area. By examining various immediate and long-range alternatives, the MWA Water Supply Study furthered the work initiated by the NEWS Study. One of the components examined in detail was conservation and demand

reduction. This component was chosen as a viable element after a series of workshops with the public and water resources specialists (more information on this aspect can be found in the Public Involvement Appendix). Amplifying this public sentiment were existing education campaigns to conserve water, as well as several instances of emergency water use restrictions incurred in 1977.

During the year of 1977, several areas of the country experienced drought or shortage situations to varying degrees. The MWA, unfortunately, was not excluded from this occurrence. In Maryland and Virginia, conservation and demand reduction measures were implemented to counteract two distinctly different situations. The situation on the Maryland side of the Potomac River was attributed to mechanical failure, while the reason for attempting to decrease water use in Virginia was the direct result of natural occurrences.

On 6 July 1977, an electrical fire at the Potomac River Water Treatment Plant of the Washington Suburban Sanitary Commission (WSSC) system caused several pumps to cease operation. Several pressure zones were directly affected, resulting in the imposition of emergency restrictions designed to curtail all but essential use of water. Fortunately, water was still available through the Patuxent Water Treatment Plant and from District of Columbia and Rockville system interconnections. Not a prolonged situation, the emergency restrictions were removed shortly thereafter, but the effectiveness of these restrictions was immediately proven.

The situation on the Virginia side of the Potomac River was of a slightly different nature, but it also served to illustrate the effectiveness of conservation and demand reduction measures. The Fairfax County Water Authority (FCWA) was experiencing below-average rainfall in the drainage basin of its supply source, the Occoquan Creek Reservoir. The situation worsened in the fall of 1977 as the Reservoir experienced severe drawdown. This situation, however, was not restricted to the FCWA; eventually, 16 Virginia counties were declared drought disaster areas. Consequently, the Commonwealth of Virginia enacted emergency legislation implementing conservation and demand reduction techniques. The FCWA drought situation did not totally resolve itself until November of that same year.

In response to the situation in 1977, various jurisdictions enacted legislation that in some way affected the degree of water use in the MWA. In May 1978, the Maryland General Assembly enacted legislation effective 1 January 1979 which altered previous plumbing regulations by incorporating water-saving plumbing fixtures into new residential and non-residential construction. This Bill is presented as Figure G-12.

On 6 July 1977, the District of Columbia adopted the "Water Conservation Act of 1977." This legislation requires that "all plumbing fixtures and devices installed in a building, structure or premise in the District of Columbia shall be of a water saving design approved by the Mayor." Included as part of this law is a presentation of maximum allowable use rates for specific devices. The Act also indicates that replacement of existing devices will be accomplished with water-saving fixtures. The "Water Conservation Act of 1977" went into effect 1 November 1977 and is included as Figure G-13.

The Commonwealth of Virginia, subsequent to its 1977 drought experience, enacted legislation allowing the various jurisdictions within the Commonwealth to develop ordinances and regulations pertaining to water conservation and water shortage

emergencies. Still concerned with present problems in the Commonwealth and recognizing the future importance of the water resource, the Virginia General Assembly passed a resolution addressing water conservation. This resolution requested the Board of Education to include in its curriculum methods to educate persons as to the benefits and means of practicing water conservation. This House Joint Resolution is presented as Figure G-14.

The examination of conservation and demand reduction as a viable component of the MWA Water Supply Study began September 1977. Several months later, the President issued a statement dealing with water conservation and its designation as a National priority. The President's Water Policy Message of 6 June 1978 is presented in Figure G-15. Subsequent to his Message, the President issued a memorandum addressing specific items relating to conservation. Already incorporated into the planning activities of the MWA Water Supply Study, conservation and demand reduction considerations became a National concern and as such their importance in addressing the water supply problem in the MWA has been heightened.

Since the publication of the Draft Progress Report for the MWA Water Supply Study in August 1979, several events have served to further the notion that water conservation is a viable concept. In recognition of the water shortage situations in the MWA, the Metropolitan Washington Council of Governments drafted a Water Supply Emergency Agreement (WSEA) in 1978. Contained within the agreement is a Water Supply Emergency Plan (WSEP) which details emergency actions and curtailments that would be implemented in the event of Potomac River shortages. By addressing means to conserve water during shortage periods, this plan complements the Potomac Low Flow Allocation Agreement, which is designed primarily to distribute available supply during times of a water shortage. In December 1979 this Water Supply Emergency Agreement was approved by the local governments. Signatories to this agreement are now required to observe the Water Supply Emergency Plan which is reproduced as Annex G-I to this appendix.

In response to unseasonably dry weather in the fall of 1980, which continued into the winter of 1981, several Virginia jurisdictions imposed water use restrictions on their residents. Fairfax County, Prince William County, and the City of Alexandria instituted rationing plans based on elements of the Water Supply Emergency Agreement. Additionally, the State of Maryland developed a drought and water shortage response plan (August 1981) which outlines actions to be taken by the State agencies to mitigate drought impacts. The State of Maryland, through the Water Resources Administration (WRA) is also developing a state-wide water conservation program which is to be an on-going activity providing information and assistance to state residents. The Mayor's Office of the District of Columbia is also currently involved in the development of procedures to institute a water conservation program.

MWA WATER USE PATTERNS

The development of the baseline water demands presented in Appendix D - Supplies, Demands, and Deficits, as well as the development of the water conservation scenarios discussed in this appendix, necessitated the collection of water use data and its incorporation into the water demand model. The purpose of this section is to present results of this water use survey, discuss the conservation measures considered, present the water conservation scenarios developed for the study, and to present general estimates of costs associated with implementation.

FIGURE G-12

MARYLAND CONSERVATION LAW

CHAPTER 862

(House Bill 44)

AN ACT concerning

Plumbing Fixtures — Water Conservation

FOR the purpose of requiring the use of water-conserving water closets, *urinals,* sink faucets and showerheads in buildings; prohibiting the sale of plumbing fixtures which are not water conserving; *providing for the enforcement of the prohibitions of this Act by local plumbing inspectors;* granting rule-making authority; *providing for definitions;* and providing a penalty.

BY adding to

Article 43 — Health
Section 325D
Annotated Code of Maryland
(1971 Replacement Volume and 1977 Supplement)

SECTION 1. BE IT ENACTED BY THE GENERAL ASSEMBLY OF MARYLAND, That section(s) of the Annotated Code of Maryland be repealed, amended, or enacted to read as follows:

Article 43 — Health

325D. WATER-CONSERVING FIXTURES REQUIRED. DEFINITIONS.

(A) IN GENERAL. IN THIS SECTION THE FOLLOWING WORDS HAVE THE MEANINGS INDICATED:

(1) "APPROVED SHOWERHEAD" MEANS ANY AUTOMATIC FLOW SHOWERHEAD USING NO MORE THAN THREE GALLONS OF WATER PER MINUTE, WITH THE RATE BASED ON A PRESSURE AT THE FIXTURE OF 40-50 POUNDS PER SQUARE INCH.

LAWS OF MARYLAND

(2) "APPROVED SINK FAUCET FOR A PUBLIC FACILITY" MEANS ANY FAUCET WITH SPRING-LOADED VALVES OR OTHER DEVICES THAT STOP THE FLOW OF WATER UPON RELEASE OF THE HANDLE OR THAT STOP THE FLOW OF WATER AFTER NOT MORE THAN ONE GALLON OF WATER HAS FLOWED THROUGH THE FITTING.

(3) "APPROVED SINK FAUCET FOR PRIVATE USE" MEANS ANY FAUCET USING NO MORE THAN-FOUR GALLONS OF WATER PER MINUTE, WITH THE RATE BASED ON A PRESSURE AT THE FIXTURE OF 40-50 POUNDS PER SQUARE INCH.

(4) "APPROVED WATER CLOSET" MEANS ANY WATER CLOSET USING NO MORE THAN 3½ GALLONS OF WATER PER FLUSH, WITH THE RATE BASED ON A PRESSURE AT THE FIXTUE OF 40-50 POUNDS PER SQUARE INCH.

(5) "APPROVED URINAL" MEANS ANY SINGLE, FLUSH-TYPE URINAL USING NO MORE THAN 1½ GALLONS OF WATER PER FLUSH, WITH THE RATE BASED ON A PRESSUE FIXTURE OF 40-50 POUNDS PER SQUARE INCH.

(6) "BUILDING" INCLUDES ANY BUILDING OR STRUCTURE, THE INITIAL CONSTRUCTION OF WHICH COMMENCED ON OR AFTER JANUARY 1, 1979.

(7) "CONSTRUCTED" MEANS THE BUILDING, INSPECTING AND SUPERVISING OF NEW STRUCTURES AND THE INSTALLING OF EQUIPMENT REQUIRED IN CONNECTION WITH THE NEW STRUCTURES.

(8) *"LOCAL PLUMBING INSPECTORS" MEANS THE INSPECTORS OF THE APPROPRIATE AGENCIES OR UNITS OF EACH COUNTY AND MINICIPAL GOVERNMENT IN THE STATE WHO INSPECT THE INSTALLATION OF PLUMBING FIXTURES AND DEVICES AND WATER, DRAINAGE, AND SEWAGE SYSTEMS.*

(9) "REMODELED" MEANS THE COMPLETE RECONSTRUCTION OR THE RELOCATION OF A WHOLE PLUMBING SYSTEM TO ANOTHER PART OF A BUILDING.

(10) "SECRETARY" MEANS THE SECRETARY OF THE DEPARTMENT OF LICENSING AND REGULATION.

(B) SALES (1) A PERSON MAY NOT SELL ANY PLUMBING FIXTURE WHICH IS NOT AN APPROVED PLUMBING FIXTURE AS DEFINED IN SUBSECTION (A).

(2) THE *LOCAL PLUMBING INSPECTORS* SHALL ENFORCE THE PROHIBITION AGAINST THE SALE OF ANY PLUMBING FIXTURES WHICH ARE NOT WATER-CONSERVING IN THE INTERESTS OF ENSURING THAT THE CAPACITIES FOR WASTEWATER TREATMENT OF MUNICIPAL SEWAGE TREATMENT FACILITIES AND PRIVATE ON-SITE WASTEWATER DISPOSAL SYSTEMS ARE NOT EXCEEDED.

(C) REQUIRED WATER-CONSERVING FIXTURES AND DEVICES. EXCEPT AS PROVIDED UNDER SUBSECTION (D). THE FOLLOWING FIXTURES OR DEVICES SHALL BE INSTALLED, AS NECESSARY, IN BUILDINGS CONSTRUCTED OR REMODELED AFTER JANUARY 1, 1979:

(1) APPROVED WATER CLOSETS IN EVERY BUILDING

(2) *APPROVED URINALS, IN EVERY BUILDING.*

(3) APPROVED SINK FAUCETS FOR PRIVATE USE, IN PRIVATE RESIDENCES AND IN BUILDINGS WITH RESTROOMS NOT INTENDED FOR PUBLIC USE AND IN HOTELS, MOTELS AND DORMITORIES.

(4) APPROVED SINK FAUCETS FOR A PUBLIC FACILITY, IN BUILDINGS WITH RESTROOMS INTENDED FOR PUBLIC USE EXCEPT IN HOTELS, MOTELS AND DORMITORIES.

(5) APPROVED SHOWERHEADS, IN EVERY BUILDING.

(D) *ENFORCEMENT SUSPENDED. ENFORCEMENT OF THIS SECTION MAY BE SUSPENDED FOR A SPECIFIED PERIOD OF TIME IF IT IS DETERMINED BY THE LOCAL PLUMBING INSPECTORS THAT:*

(1) THERE IS AN INADEQUATE SUPPLY OF APPROVED WATER CLOSETS, APPROVED SINK FAUCETS OR APPROVED SHOWERHEADS, OR WATER-CONSERVING DEVICES INTENDED FOR ATTACHMENT TO WATER CLOSETS, SINK FAUCETS OR SHOWERHEADS TO ALLOW THE FIXTURES TO QUALIFY AS APPROVED FIXTURES, UNDER SUBSECTION (A); OR

(2) THE CONFIGURATION OF A DRAINAGE SYSTEM FOR A BUILDING REQUIRES A GREATER QUANTITY OF WATER TO ADEQUATELY FLUSH THE SYSTEM THAN IS DELIVERED BY APPROVED FIXTURES: OR

(3) *THERE WOULD BE AN ADVERSE EFFECT UPON AN HISTORIC RESTORATION.*

(E) RULES. THE SECRETARY SHALL PROMULGATE THOSE RULES DEEMED NECESSARY TO CARRY OUT THE PURPOSES OF AND TO ENFORCE THIS SECTION, INCLUDING THE FORMULATION OF STANDARDS FOR ACCEPTABLE FIXTURES AND DEVICES WHICH REDUCE WATER CONSUMPTION AND MEET REQUIREMENTS OF SAFETY AND SANITATION. THE STANDARDS SHALL INCLUDE LISTINGS OF ACCEPTABLE FIXTURES AND DEVICES AVAILABLE COMMERCIALLY. *THESE RULES SHALL BE INCORPORATED INTO AND BE PART OF THE STATE PLUMBING CODE.*

(F) FORFEITURES. ANY PERSON VIOLATING ANY OF THE PROVISIONS OF THIS SECTION SHALL FORFEIT TO THE STATE NOT LESS THAN $25 NOR MORE THAN $500 FOR EACH VIOLATION. EACH DAY THAT THE VIOLATION CONTINUES CONSTITUTES A SEPARATE OFFENSE.

SECTION 2. AND BE IT FURTHER ENACTED, That this Act shall take effect January 1, 1979.

Approved May 29, 1978.

FIGURE G-13

COUNCIL OF THE DISTRICT OF COLUMBIA

NOTICE

October 4, 1977

D.C. LAW 2-21

"Water Conservation Act of 1977".

Pursuant to Section 412 of the District of Columbia Self-Government and Governmental Reorganization Act (PL 93-198), the Act, the Council of the District of Columbia adopted Bill No. 2-60 on first and second readings May 31, 1977, and June 14, 1977, respectively. Following the signature of the Mayor on July 6, 1977, this legislation was assigned Act No. 2-52, published in the July 29, 1977, edition of the *D.C. Register*, and transmitted to both Houses of Congress for a 30-day review, in accordance with Section 602(c)(1) of the Act.

The Council of the District of Columbia hereby gives notice that the 30-day Congressional Review Period has expired and, therefore, cites the following legislation as D.C. Law 2-21, effective September 23, 1977.

STERLING TUCKER
Chairman of the Council

(Vol. 24, D.C. Register, 905, July 29, 1977)

ACTIONS OF THE CITY COUNCIL

ACTS

AN ACT
2-52

IN THE COUNCIL OF THE DISTRICT OF COLUMBIA
July 6, 1977

To amend the District of Columbia plumbing code to require the installation of water conservation devices or fixtures.

BE IT ENACTED BY THE COUNCIL OF THE DISTRICT OF COLUMBIA, That this act may be cited as the "Water Conservation Act of 1977".

Sec. 2. Regulation 72-19, enacted August 26, 1972 (relating to the 1972 Plumbing Code of the District of Columbia), is amended as follows:

(a) In section 302 add "(See Section 413)" after "Water Closets and Urinals";

(b) In section 303 add "(See Section 413)" after "FLUSHING DEVICES";

(c) In section 304 add "(See Section 413)" after "LAVATORIES";

(d) In section 305 add "(See Section 413)" after "BATHTUBS";

(e) In section 306 add "(See Section 413)" after "SHOWERS";

(f) In section 307 add "(See Section 413)" after "LAUNDRY TRAYS";

(g) In section 308 add "(See Section 413)" after "SINKS";

(h) A new section 413 is added to read as follows:

"413 WATER CONSERVATION (Effective November 1, 1977)

"413-1 All plumbing fixtures and devices installed in a building, structure or premise in the District of Columbia shall be of a water saving design approved by the Mayor. In addition, each fixture and device listed below which is installed in the District of Columbia shall not exceed the following water usage rate:

"Water closets	3.5 gallons per flush
"Urinals	3.0 gallons per flush
"Showerheads	3.0 gallons per minute
"Lavatory and Kitchen sink faucets	4.0 gallons per minute

"Aerators shall be installed on all newly installed lavatory and kitchen sink faucets.

"413-2 All newly installed faucets on lavatories located in restrooms intended for public use shall be of the metering self-closing type.

"413-3 Car wash installations, ornamental fountains and cooling towers shall be equipped with a water recycling system approved by the Mayor. All existing uses shall be equipped with the requisite recycling devices before July 1, 1978."

Sec. 3. This act shall take effect as provided in section 602(c) of the District of Columbia Self-Government and Governmental Reorganization Act.

FIGURE G-14

LD6039205

HOUSE JOINT RESOLUTION NO. 268

Offered January 19, 1979

Requesting the Board of Education to encourage the inclusion of information on residential water conservation in the public school curriculum.

Patrons-McClanan, Murray, Barry, Hailey, Robinson, Plum, Jones, J. S., and O'Brien, J. W.

Referred to the Committee on Education

WHEREAS, water has long been held, like air, to be virtually free and available in unlimited quantities; and

WHEREAS, the continued growth of our population and the environmental consequences of water use at its present increasing rate, and a wide-spread recent drought in the Commonwealth, have caused a new awareness of our need to conserve our water resources; and

WHEREAS, rising costs, both financial and environmental, of making "new water" available have caused more attention to be turned to ways of reducing our per capita consumption of water without sacrifice to our standard of living; and

WHEREAS, devices, methods, techniques, appliances, and other procedures for water consumption reduction exist and others are being developed; and

WHEREAS, full realization of the benefits of the new water-saving technology will require educating Virginians as to the need for water conservation and the means by which water conservation can best be accomplished; and

WHEREAS, such education can be effectively accomplished among the youth of Virginia by including in the Virginia public school curriculum the need for water conservation and the techniques by which this can be accomplished; now, therefore, be it

RESOLVED by the House of Delegates, the Senate concurring, That the Board of Education is requested to encourage inclusion in the curriculum of Virginia's public schools, in a practical and meaningful way, (1) the need for water conservation in Virginia, (2) how individuals can accomplish such conservation in their own homes, (3) information about appliances, devices, practices and techniques which achieve water consumption reduction, (4) the economic and ecological benefits of water consumption reduction. In undertaking this task, the Board of Education is urged to work cooperatively with the State Water Control Board, Virginia Water Resources Research Center, and all other relevant agencies, groups and individuals concerned with the development and promotion of water conservation technology.

FIGURE G-15

Water Conservation

Managing our vital water resources depends on a balance of supply, demand and wise use. Using water more efficiently is often cheaper and less demanding to the environment than developing additional supplies. *While increases in supply will still be necessary, these reforms place emphasis on water conservation and make clear that this is now a national priority.*

In addition to adding the consideration of water conservation to the Principles and Standards, the initiatives I am taking include:

Directives to all Federal agencies with programs which affect water supply or consumption to encourage water conservation, including:

— making appropriate community water conservation measures a condition of the water supply and wastewater treatment grant and loan programs of the Environmental Protection Agency, the Department of Agriculture and the Department of Commerce;

— integrating water conservation requirements into the housing assistance programs of the Department of Housing and Urban Development, the Veterans Administration and the Department of Agriculture;

— *providing technical assistance to farmers and urban dwellers on how to conserve water through existing programs of the Department of Agriculture, the Department of the Interior and the Department of Housing and Urban Development;*

— requiring development of water conservation programs as a condition of contracts for storage or delivery of municipal and industrial water supplies from federal projects;

— requiring the General Services Administration, in consultation with affected agencies, to establish water conservation goals and standards in Federal buildings and facilities;

— *encouraging water conservation* in the agricultural assistance programs of the Department of Agriculture and the Department of the Interior which affect water consumption in water-short areas; and

— requesting all Federal agencies to examine their programs and policies so that they can implement appropriate measures to increase water conservation and re-use.

A directive to the Secretary of the Interior to improve the implementation of irrigation repayment and water service contract procedures under existing authorities of the Bureau of Reclamation. The Secretary will:

— require that new and renegotiated contracts include provisions for recalculation and renegotiation of water rates every five years. This will replace the previous practice of 40-year contracts which often do not reflect inflation and thus do not meet the beneficiaries' repayment obligations;

— under existing authority add provisions to recover operation and maintenance costs when existing contracts have adjustment clauses;

— more precisely calculate and implement the "ability to pay" provision in existing law which governs recovery of a portion of project capital costs.

Preparation of legislation to allow States the option of requiring higher prices for municipal and industrial water supplies from Federal projects in order to promote conservation, provided that State revenues in excess of Federal costs would be returned to municipalities or other public water supply entities for use in water conservation or rehabilitation of water supply systems.

—President Carter's Water Policy Message
June 6, 1978

DATA COLLECTION AND USE DETERMINATION

Within the MWA, there are numerous public agencies and several private organizations which supply and distribute water for potable use. For analytical purposes, these facilities were aggregated into eight water service areas depicted in Figure G-16; furthermore, as a result of the work represented in the 1979 Draft Progress Report, the eight water service areas were grouped as either Potomac River users or outlying service areas. Table G-13 lists these water service areas, the agencies within each area, and the basic sources of water supply.

After determining the water supply and distribution agencies, an effort was made to obtain information on water use from these same agencies. Available information was obtained through meetings with local officials, from letter requests for information, from telephone interviews, from studies and reports, and, in some cases, from selected data file retrievals. The year 1976 was chosen as the survey year because it was the latest year for which complete records were available. During the course of this survey, private water supplies consisting primarily of individual residential and commercial well sources were found to represent a relatively small percentage of water use and, therefore, were not included in the survey of public water systems.

The date obtained from the various agencies included total monthly water production or distribution system input, metered water use by user category, and the number of meters by user category. In addition to the water use data, information was also requested on programs and incentives in the areas to encourage water conservation. Programs already in effect in some of the water service areas were expected to affect future water use and were taken into consideration in the development of the various scenarios discussed later in this section.

Because of the diverse water use types in the MWA, water use was disaggregated to several categories. Within each of the water service areas, as many as seven water use categories were identified as follows:

1. Single family residential water use,
2. Multi-family residential water use,
3. Commercial and industrial water use,
4. Government and institutional water use, including state and local government use,
5. Federal government water use,
6. Unaccounted water use,
7. Bulk sales of water.

In all of the water service areas, the first five categories represented a majority of the water used. The sixth category, unaccounted, was included to represent the difference between water released to the distribution system and total water accounted for based on records of metered water use. This category includes uses such as distribution system leakage and system deterioration, water not accounted for due to inaccurate meter readings, system blow-off, and water used directly from hydrants for municipal purposes such as street cleaning, line flushing, and fire fighting. While the unaccounted category represents a part of total water use, actual system leakage accounts for only a portion of the unaccounted category. The category of bulk sales was included to reflect contractual sales of water to another agency or water service area.

FIGURE G-16

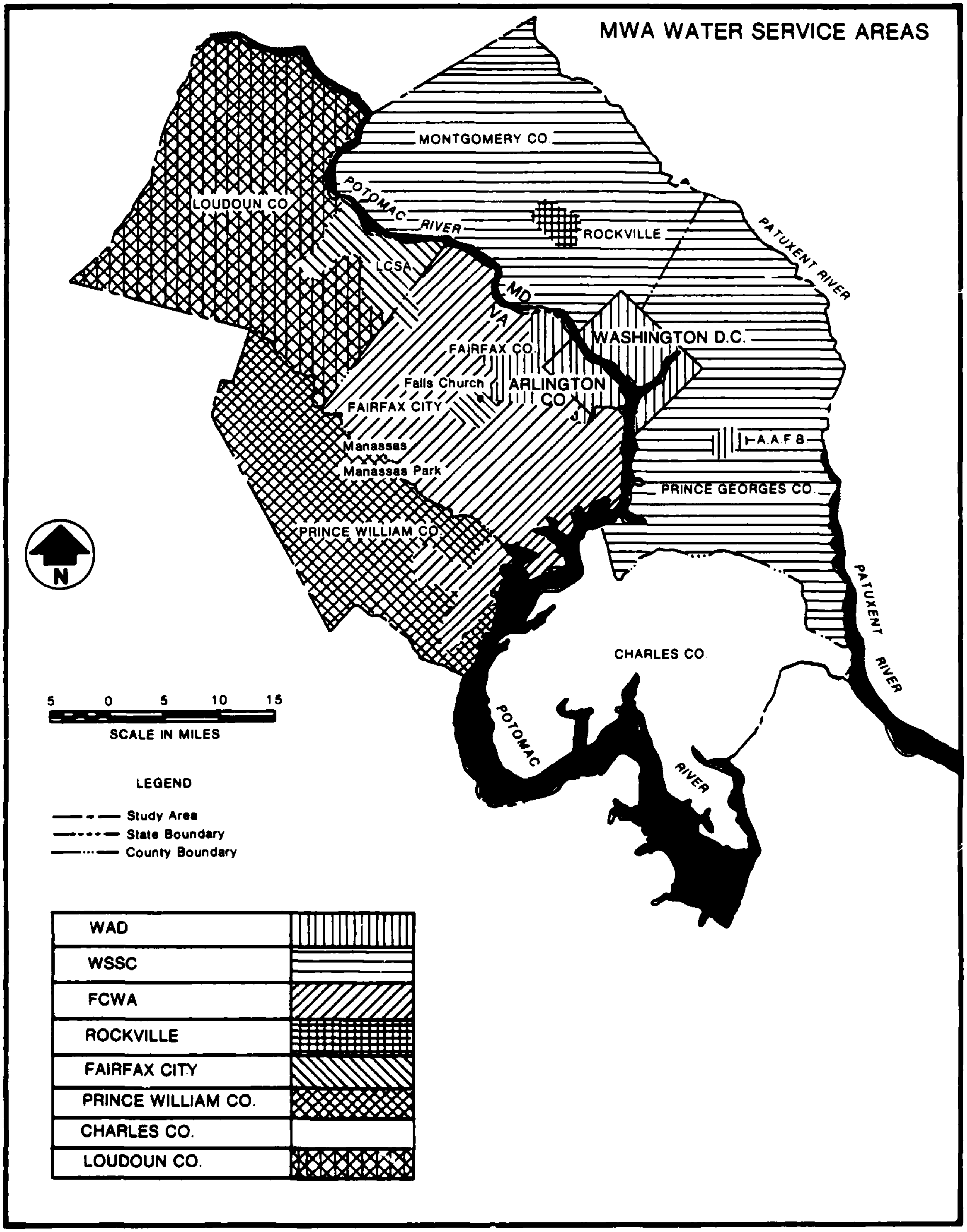

MWA WATER SERVICE AREAS
MONTGOMERY CO.
LOUDOUN CO.
POTOMAC RIVER
ROCKVILLE
PATUXENT RIVER
LCSA
MD
VA
WASHINGTON D.C.
FAIRFAX CO.
Falls Church
ARLINGTON CO.
FAIRFAX CITY
A.A.F.B.
Manassas
Manassas Park
PRINCE GEORGES CO.
PRINCE WILLIAM CO.
N
PATUXENT RIVER
CHARLES CO.
5 0 5 10 15
SCALE IN MILES
POTOMAC RIVER
LEGEND
Study Area
State Boundary
County Boundary
WAD
WSSC
FCWA
ROCKVILLE
FAIRFAX CITY
PRINCE WILLIAM CO.
CHARLES CO.
LOUDOUN CO.

TABLE G-13

WATER SERVICE AREAS AND SUPPLY SOURCES

WATER SERVICE AREA	SUPPLY SOURCE
POTOMAC RIVER USERS	
Washington Aqueduct Division (WAD)	
District of Columbia, Dept. of Environmental Services	Potomac
Falls Church	Potomac
Vienna	Potomac, Wells
Arlington County	Potomac
Washington Suburban Sanitary Commission (WSSC)	
Washington Suburban Sanitary Commission	Potomac, Patuxent
Belair-Bowie	Wells
Fairfax County Water Authority (FCWA)	
Fairfax County Water Authority	Occoquan
Virginia American Water Company	Occoquan, Wells
Occoquan-Woodbridge/Dumfries-Triangle Sanitary District	Occoquan
City of Rockville	
City of Rockville Dept. of Public Works	Potomac
OUTLYING SERVICE AREAS	
City of Fairfax	
Fairfax City	Goose Creek
Town of Herndon	Goose Creek, Wells
Loudoun County Sanitation Authority	Goose Creek
Prince William County	
Quantico Marine Base	Beaverdam Run
Quantico	Chopawamsic Creek
Manassas	Broad Run, Wells
Manassas Park	Wells
Greater Manassas Sanitary District	Wells, Broad Run
Public Well Systems	Wells
Loudoun County	
Leesburg	Wells
Public Well and Spring Systems	Wells, Springs
Charles County	
Charles County Department of Public Works	Wells
La Plata	Wells
Indian Head	Wells

Water use information to sufficient detail was not available in all cases from the purveyor records. Where this occurred, the disaggregation of water use to user categories was determined on the basis of observed (density, total water use, etc.) similarities to other areas where sufficient data were available. In cases where user data were available for previous years but not for 1976, the previously established user category shares were assumed to reflect 1976 water use as well.

The breakdown of water use in the Federal government category was facilitated by results obtained in an April 1978 study, Water Use and Conservation at Federal Facilities in the Washington, D.C. Metropolitan Area, by WAPORA, Inc. for Federal offices and facilities in 1976. Data were obtained for the following MWA water purveyors: The District of Columbia Department of Environmental Services; the Washington Suburban Sanitary Commission (WSSC); the Fairfax County Water Authority (FCWA); Rockville; Falls Church; Arlington; Alexandria; and the City of Fairfax. Federal activities housed in both "leased" and "Federally-owned" space were included and separately identified. Most of the water supply agencies classify Federal government users housed in leased space as commercial rather than government users. Therefore, the water use reported by WAPORA for Federal agencies housed in "leased" space was subtracted from the commercial water use category total to permit the identification of a separate category of Federal water use. Similarly, water use by Federal activities housed in "Federally-owned" facilities, for which it was assumed the Federal government received the water bill, was subtracted from the water utilities' records of water use by government agencies.

WASHINGTON AQUEDUCT DIVISION

The largest of the eight water service areas, the Washington Aqueduct Division (WAD) Water Service Area includes the District of Columbia, Arlington County, the City of Falls Church, and the Town of Vienna. Portions of Fairfax County also receive water indirectly from the WAD, but this amount is accounted for in the discussion of the Fairfax County Water Authority Water Service Area. The Potomac River is the only water supply source of the WAD. From its Potomac River intakes, located at Great Falls and Little Falls, water is conveyed to Dalecarlia Reservoir and is treated at the Dalecarlia Water Treatment Plant or at the McMillan Water Treatment Plant. Of the total water distributed in 1976, approximately 80 percent was received by the District of Columbia, while Arlington County and Falls Church received about 11 percent and 9 percent, respectively. Table G-14 presents monthly water use by each of the WAD customers for 1976 and 1977 and underscores the maximum and minimum uses. The following sections describe the current water use by jurisdiction within the WAD Water Service Area.

District of Columbia

The agency responsible for the distribution of water for the District of Columbia is the Department of Environmental Services (DES). Operating responsibilities of the DES also include wastewater collection and treatment facilities. The DES operates under the regulations promulgated by the D.C. Government, but, like the D.C. Government, is influenced by the U.S. Congress through budgetary constraints exercised by Congressional committees. In 1976, the DES distributed approximately 158 million gallons per day (mgd) to the various users. Because information was not available on water use by category, an earlier report, Evaluation of the Use of Pricing as a Tool for Conserving Water (Chiogioji, November 1973) was referenced for a breakdown of water

TABLE G-14

TOTAL WATER DISTRIBUTED BY THE WASHINGTON AQUEDUCT DIVISION
1976-1977

Month	District of Columbia (mgd)	District of Columbia (%)	Arlington County (mgd)	Arlington County (%)	Falls Church (mgd)	Falls Church (%)	Total (mgd)
Jan-76	148.8	79.6	20.6	11.0	17.6	9.4	187.0
Feb	144.8	79.9	19.6	10.8	16.9	9.3	181.3
Mar	146.8	80.7	19.5	10.7	15.7	8.6	182.0
Apr	154.8	79.7	20.9	10.8	18.4	9.5	194.1
May	156.1	79.8	21.0	10.7	18.6	9.5	195.7
Jun	178.6	79.7	24.5	10.9	21.0	9.4	224.1
Jul	181.2	80.9	24.1	10.8	18.7	8.3	224.0
Aug	178.7	80.4	23.6	10.6	20.1	9.0	222.4
Sep	168.4	80.0	22.8	10.8	19.3	9.2	210.5
Oct	153.6	79.7	21.3	11.1	17.7	9.2	192.6
Nov	144.8	78.3	22.1	12.0	18.0	9.7	184.9
Dec	142.9	77.2	24.1	13.0	18.2	9.8	185.2
Avg 1976*	158.3	79.7	22.0	11.1	18.3	9.2	198.7
Jan-77	151.8	79.4	22.6	11.8	16.7	8.8	191.1
Feb	139.3	79.7	19.7	11.3	15.7	9.0	174.7
Mar	132.2	80.0	17.8	10.7	15.3	9.3	165.3
Apr	134.1	78.8	18.6	10.9	17.6	10.3	170.3
May	149.0	78.8	20.0	10.6	20.1	10.6	189.1
Jun	171.1	80.8	20.5	9.7	20.2	9.5	211.8
Jul	187.0	81.6	21.4	9.3	20.7	9.1	229.1
Aug	184.4	81.5	20.2	8.9	21.8	9.6	226.4
Sep	178.3	79.8	22.0	9.8	23.2	10.4	223.5
Oct	160.3	78.0	24.1	11.8	21.0	10.2	205.4
Nov	151.0	80.7	18.2	9.7	18.0	9.6	187.2
Dec	152.3	81.3	18.1	9.6	17.0	9.0	187.4
Avg 1977*	157.6	80.1	20.3	10.3	18.9	9.6	196.8

NOTE: Underlined numbers represent maximum and minimum for (mgd) and (%).

*Based on total annual volume supplied divided by 366 days for 1976 and 365 days for 1977.

use by category. Additionally, information was obtained from an infiltration/inflow study (O'Brien & Gere, Consultants) in the area. The resulting water use breakdown for the DES is summarized in Table G-15.

Table G-15 includes information on water use by category and the percent use by category. Also included is the amount of the commercial/industrial and government/institutional categories accounted for by Federal government water use. Of the total Federal water use reported in the District of Columbia, 22.6 mgd was used by Federal agencies located in government-owned facilities. The remaining 1.5 mgd was used by Federal agencies occupying space in non-government facilities. There are several large water users within the area served by the DES (0.65 mgd to 2.9 mgd). Primarily affiliated with the Federal government, these 10 agencies (including Andrews Air Force Base and the Pentagon) account for approximately 50 percent of the total Federal use. Perhaps of more significance is that the combined daily use of these 10 agencies represents about eight percent of the total water provided by the DES.

Arlington County

Arlington County provides for its own water utility service under authority of the Virginia Code. The 1976 water use for the County averaged 22 mgd, or approximately 11 percent of the total WAD Water Service Area. Because Arlington County maintains water use records on a fiscal year basis, a conversion of this information to calendar year was required. This was done by examining the categorical breakdown of water use for FY 1975 and determining the percent share of each water use category. These percent shares were then applied to the calendar year 1976 information. The resulting breakdown of water use by category is presented in Table G-15.

Most of the water use in Arlington County is residential. Of the total 67 percent is domestic use with a large proportion consisting of multi-family residential use. Several government institutions also use large amounts of water. Ft. Meyer used 0.51 mgd or slightly more than two percent of the total County water use, while National Airport's use of 1.30 mgd accounted for almost six percent of the total Arlington County 1976 water use.

City of Falls Church

As indicated previously, the City of Falls Church accounts for approximately nine percent of the total water used in the WAD Water Service Area. A portion of this water is sold wholesale to the Town of Vienna and the Fairfax County Water Authority. Because Falls Church maintains water use records by fiscal year, the 1976 water use figures were based on calendar year information presented in Table G-14. Based on discussions with representatives of the Department of Public Utilities, it was assumed that water use in Falls Church is similar to that in Arlington County. The resulting information for water use by category is presented in Table G-15.

Town of Vienna

The Town of Vienna buys a majority of its water from the City of Falls Church through a contractual arrangement. This contract is based on 2.0 mgd being supplied to the Town. The Town of Vienna also obtains 0.3 mgd from groundwater sources. In 1976, the Town of Vienna purchased approximately 2.2 mgd of water from Falls Church. With the groundwater sources included, a total of 2.5 mgd was used. Based on information obtained from the Vienna Director of Public Works and Vienna's similarities to other

TABLE G-15

WASHINGTON AQUEDUCT DIVISION
WATER USE BY CATEGORY - 1976
(MGD)

Jurisdiction	Single-Family		Multi-Family		Commercial/ Industrial		Government/ Institutional		Federal[1]		Unaccounted		Bulk Sales[2]		Total	
District of Columbia	31.1	(19.6)	50.0	(31.6)	12.7	(8.0)	10.5	(6.7)	24.1	(15.2)	29.9*	(18.9)	0	(0)	158.3	(100.0)
Arlington County	6.25	(28.4)	8.54	(38.8)	1.29	(5.9)	0.44	(2.0)	3.01	(13.7)	2.47	(11.2)	0	(0)	22.0	(100.0)
City of Falls Church	3.54	(28.4)	4.84	(38.9)	2.24	(18.0)	0	(0)	0.44	(3.5)	1.39	(11.2)	0	(0)	12.45	(100.0)
Town of Vienna	1.607	(64.3)	0.033	(1.3)	0.41	(16.4)	0	(0)	0	(0)	0.45	(18.0)	0	(0)	2.5	(100.0)
Total	42.497	(21.8)	63.413	(32.5)	16.64	(8.5)	10.94	(5.6)	27.55	(14.1)	34.21	(17.5)	0	(0)	195.25	(100.0)

NOTE: Numbers in parentheses represent the percentage of total water use by category.

[1]Federal Component Based on 1978 WAPORA Study for EPA.

[2]Bulk Sales represent sales within the service area for miscellaneous use.

*Approximately 4% attributable to system losses and meter slippage.

areas in the MWA, water use by category was determined. Presented in Table G-15, the 1976 water use data show that the Town is largely residential with many of the commercial establishments small in size. Total water use information by category for the WAD Water Service Area is also presented in Table G-15. The total 1976 water use of 195 mgd accounted for about 47 percent of the total public system water use in the MWA. The service area total of 195.25 differs slightly from the total distributed by the WAD because a bulk sale of 3.64 mgd to the FCWA is deleted and the Town of Vienna's groundwater source of 0.3 mgd is included.

WSSC WATER SERVICE AREA

The Washington Suburban Sanitary Commission (WSSC) is the major supply agency for the designated WSSC Water Service Area. The areas included in the WSSC Water Service Area are Prince Georges County, Montgomery County, and Bowie, Maryland. The older portions of the City of Bowie are served by the Bowie Department of Public Works from groundwater supplies; the more recent development in the City (the Bowie-Collington area) is served by WSSC. Since most of the future growth in the City will also be supplied by the WSSC, all of Bowie has been included in the WSSC Water Service Area. The parts of Howard County supplied by WSSC are not considered since Howard County is outside the study area.

Washington Suburban Sanitary Commission

The WSSC was created in 1918 by an Act of the Maryland General Assembly to provide water and wastewater service to Montgomery and Prince Georges Counties, Maryland. The areas not included as part of the WSSC are the City of Rockville in Montgomery County, the City of Bowie, and Andrews Air Force Base in Prince Georges County. The WSSC receives its water from two major sources. The Patuxent River Reservoirs of Triadelphia and Rocky Gorge provide water to the eastern portion of Montgomery County as well as Prince Georges County. The Potomac River serves as the main source of water supply to the area and, with its expanded intake, the WSSC is capable of withdrawing up to 400 mgd. The WSSC also provides a small amount of water (1.5 mgd) to Howard County on a wholesale basis. Anne Arundel County has approached WSSC for water, but presently no commitments have been made.

The total water production by WSSC in 1976 amount to 138.1 mgd (including 1.5 mgd sold to Howard County). As water use information by category had not yet been computed, 1975 breakdowns of water use were applied to 1976 data. This information was presented by Black and Veatch in a Report on Considerations Regarding Adoption of an Excess Water Use Charge by the WSSC, 1977. The results of this effort are shown in Table G-16.

City of Bowie

That portion of the City of Bowie not served by the WSSC receives water from the City of Bowie Department of Public Works. The City of Bowie operates and maintains the water supply system. Water provided by the City of Bowie is drawn from five wells with a total maximum capacity of 5.0 mgd based on the size of the water treatment plant. As shown in Table G-16, total water production in fiscal year 1976 amounted to almost 2.5 mgd with the residential category using over 83 percent of this total.

Total 1976 water use by the WSSC Water Service Area amounted to approximately 141 mgd. Over 70 percent of the 1976 use was attributed to the residential category with single family residences accounting for over 43 percent of the total water used. The

smallest user category, in terms of total water used, is the Federal category, which used less than four percent of the total 1976 water pumped. A summary of total WSSC Service Area water use is presented in Table G-16. These figures indicate that water use in the WSSC Water Service Area was approximately 33 percent of total MWA water use, making this the second largest service area in the MWA.

FCWA WATER SERVICE AREA

The Fairfax County Water Authority (FCWA) Water Service Area provides service to a large portion of the Northern Virginia area. The water service area consists of the Fairfax County Water Authority, the Virginia American Water Company, and the Occoquan-Woodbridge/Dumfries Triangle Sanitary District. The water service area also provides water to Prince William County and Fairfax City on a bulk basis. Three sources of water are used in the water service area. The principal source is the Reservoir on Occoquan Creek. Water is also purchased from Falls Church and Fairfax City. The third water source, though relatively small, is groundwater, which is treated at the FCWA facilities. Table G-17 presents information on total monthly water use within the service area which indicates that over 90 percent of the water is obtained from the Occoquan Reservoir.

Fairfax County Water Authority

The area served by the FCWA includes all of Fairfax County with the exception of the following areas: Town of Vienna, City of Fairfax, City of Falls Church and City of Alexandria. The FCWA also sells water to the Virginia American Water Company (VAWCo), the Occoquan-Woodbridge/Dumfries Triangle (OWDT) Sanitary District, the Prince William County Water Service Area, and the City of Fairfax. The FCWA maintains records for each of the five retail categories it classifies. The retail users are divided among the following: single family residential, multi-family residential, apartments, commercial/industrial, municipal/institutional. In addition to the above, FCWA sells water on a wholesale basis to Dulles International Airport, Fort Belvoir, and the D.C. Reformatory. Based on these classifications, water use by category was determined and is shown in Table G-18. The Bulk category represents water sold wholesale for miscellaneous purposes. It does not include water sold by FCWA to the Prince William County or Fairfax City Service Area.

Virginia American Water Company

The Virginia American Water Company (VAWCo) provides water to the City of Alexandria and the Dale City area of Prince William County. Approximately 15 mgd of water is bought from the FCWA and the VAWCo supplements this with 2.0 mgd from its own wells. The water use categories designated by the VAWCo were converted to the classifications used in this study and the resulting water use by category for each district is shown in Table G-18.

TABLE G-16

WSSC SERVICE AREA
WATER USE BY CATEGORY - 1976
(mgd)

Jurisdiction	Single-Family		Multi-Family		Commercial/ Industrial		Government/ Institutional		Federal[1]		Unaccounted		Bulk Sales[2]		Total	
Washington Suburban Sanitary Commission	59.5	(43.1)	38.0	(27.5)	17.84	(12.9)	3.58	(2.6)	4.98	(3.6)	12.7	(9.2)	1.5	(1.1)	138.1	(100.0)
City of Bowie	2.08	(83.9)	0	(0)	0.07	(2.8)	0.04	(1.6)	0	(0)	0.29	(11.7)	0	(0)	2.48	(100.0)
Total	61.58	(43.8)	38.0	(27.0)	17.91	(12.8)	3.62	(2.6)	4.98	(3.5)	12.99	(9.2)	1.5	1.1)	140.58	(100.0)

NOTE: Numbers in parentheses represent the percentage of total water use by category.

[1]Federal component based on 1978 WAPORA Study for EPA.

[2]Bulk Sales represent average amount sold to Howard County.

TABLE G-17

FCWA SERVICE AREA SOURCES OF WATER

1976

Month	OCCOQUAN (mgd)*	OCCOQUAN (%)	PURCHASED (mgd)	PURCHASED (%)	WELLS (mgd)	WELLS (%)	TOTAL (mgd)
Jan	51.06	91.2	4.14	7.4	0.77	1.4	55.97
Feb	51.88	92.3	3.56	6.3	0.76	1.4	56.20
Mar	53.10	93.4	2.99	5.3	0.75	1.4	56.20
Apr	61.56	91.8	4.71	7.0	0.77	1.1	67.02
May	61.23	91.4	5.06	7.6	0.72	1.1	67.01
Jun	78.62	90.6	6.23	8.2	0.92	1.2	75.77
Jul	66.57	92.0	4.99	6.9	0.79	1.1	72.35
Aug	65.79	89.6	6.84	9.3	0.76	1.0	73.39
Sep	62.72	89.8	6.40	9.2	0.74	1.1	69.86
Oct	55.96	89.6	5.87	9.4	0.63	1.0	62.46
Nov	55.28	89.6	5.80	9.4	0.64	1.0	61.72
Dec	54.90	88.9	6.25	10.1	0.62	1.0	61.77
Avg	59.06	90.8	5.24	8.1	0.74	1.1	65.04

*Includes untreated water sold wholesale.

TABLE G-18

FCWA SERVICE AREA
WATER USE BY CATEGORY - 1976
(mgd)

Jurisdiction	Single-Family		Multi-Family		Commercial/ Industrial		Government/ Institutional		Federal [1]		Unaccounted		Bulk Sales [2]		Total	
Fairfax County Water Authority	21.34	(49.3)	7.78	(18.0)	3.47	(8.0)	2.43	(5.6)	3.31	(7.6)	4.08	(9.4)	0.9	(2.1)	43.31	(100.0)
Virginia-American Water Company																
Alexandria	3.46	(23.2)	6.74	(45.2)	2.94	(19.7)	1.04	(7.0)	0.46	(3.1)	0.26	(1.8)	0	(0)	14.9	(100.0)
Dale City	1.88	(88.7)	0	(0)	0.098	(4.6)	0.075	(3.5)	0	(0)	0.067	(3.2)	0	(0)	2.12	(100.0)
OWDT Sanitary District	1.972	(46.5)	0.746	(17.6)	0.765	(18.1)	0.149	(3.5)	0	(0)	0.608	(14.3)	0	(0)	(4.24)	(100.0)
Total	28.652	(44.4)	15.266	(23.6)	7.273	(11.3)	3.694	(5.7)	3.77	(5.8)	5.015	(7.8)	0.9	(1.4)	64.57	(100.0)

Note: Numbers in parentheses represent the percentage of total water use by category.

1 Federal Component Based on 1978 WAPORA Study for EPA.

2 Bulk Sales Represent Sales within the service area for miscellaneous use; does not include 0.43 mgd sold to Fairfax City or 0.03 mgd sold to the Greater Manassas Sanitary District.

OWDT Sanitary District

The Occoquan Woodbridge - Dumfries Triangle (OWDT) Sanitary District is entirely within Prince William County and operates under authority of the Virginia Water and Sewer Act. The Sanitary District purchases all of its water from the FCWA and distributes the water through a system operated and maintained by the Sanitary District. Based on monthly water use records and information provided by Sanitary District representatives, water use by category was determined and is presented in Table G-18. Table G-18 also contains information on total water use by category for the FCWA Water Service Area. The average use of 64 mgd by the Water Service Area ranks it as the third largest in terms of water use in the MWA, accounting for approximately 15 percent of the total 1976 water use.

ROCKVILLE WATER SERVICE AREA

The City of Rockville Water Service Area consists of the area served by the Rockville Department of Public Works: the area enclosed within the City corporate limits with the exception of approximately 1100 homes that are served by the WSSC. It uses the Potomac River as its source of water. The Rockville Department of Public Works operates under City Charter and is responsible for providing, among other things, water and wastewater services within the corporate limits. Water use records for 1976 were otained by month and are reflected in Table G-19. These records indicate that average use approximates 4 mgd. Using information obtained from computerized records, water use was broken down by user category and is presented in Table G-20.

Based on the information presented in Table G-21, the four service areas which comprise the Potomac River users had an average 1976 water use of 403 million gallons per day. This figure represented more than 95 percent of the total recorded use in the MWA. Of the four service areas, the Washington Aqueduct withdrawals accounted for almost 50 percent of the water use while the WSSC reported use figures approximating 35 percent of the Potomac users total.

FAIRFAX CITY WATER SERVICE AREA

Consisting of the City of Fairfax, the Loudoun County Sanitation Authority (LCSA), and the Town of Herndon, the Fairfax City Water Service Area has as its source of water the Goose Creek and Beaverdam Reservoirs. The following is a brief description of these systems and their water use characteristics.

City of Fairfax

The City of Fairfax Department of Water and Sewer Services provides water on a retail basis to the City of Fairfax. Water is sold to the LCSA and the Town of Herndon on a wholesale basis while a reversible interconnection is also maintained with FCWA. This distribution of water within the Water Service Area is presented in Table G-22. Based on fiscal year 1976 water use information, a breakdown of water use by category was accomplished. This disaggregation of use is presented in Table G-23 and indicates that a relatively large amount of water is attributed to the unaccounted use category.

TABLE G-19

ROCKVILLE SERVICE AREA MONTHLY
WATER PRODUCTION - 1976

Month	mgd	Month	mgd
January	3.73	July	4.52
February	3.75	August	4.80
March	3.57	September	4.58
April	4.07	October	3.76
May	4.09	November	3.76
June	5.02	December	3.74
Average	4.11		

TABLE G-20

ROCKVILLE SERVICE AREA
WATER USE BY CATEGORY - 1976
(mgd)

Category	Total	Percent of Total
Single Family	1.924	46.8
Multi-Family	0.561	13.6
Commercial/Industrial	1.068	26.0
Government/Institutional	0.317	7.7
Federal *	0.048	1.2
Unaccounted	0.193	4.7
Bulk	0	0
Total	4.111	100.0

* Federal Component Based on 1978 WAPORA Study for EPA.

TABLE G-21

POTOMAC RIVER USERS
WATER USE BY CATEGORY - 1976
(mgd)

Water Service Area	Single-Family		Multi-Family		Commercial/ Industrial		Government/ Institutional		Federal [1]		Unaccounted		Bulk Sales [2]		Total	
Washington Aqueduct Division	42.497	(21.8)	63.413	(32.5)	16.64	(8.5)	10.94	(5.6)	27.55	(14.1)	34.21	(17.5)	0	(0)	195.25	(100.0)
Washington Suburban Sanitary Commission	61.58	(44.3)	38.00	(27.3)	17.91	(12.9)	3.62	2.6)	4.98	(3.6)	12.99	(9.3)	0	(0)	139.08	(100.0)
Fairfax County Water Authority	28.652	(44.4)	15.266	(23.6)	7.273	(11.3)	3.694	(5.7)	3.77	(5.8)	5.015	(7.8)	0.9	(1.4)	64.57	(100.0)
City of Rockville	1.924	(46.8)	0.561	(13.6)	1.068	(26.0)	0.317	(7.7)	0.048	(1.2)	0.193	(4.7)	0	(0)	4.111	(100.0)
Total	134.653	(33.4)	117.24	(29.1)	42.891	(10.7)	18.571	(4.6)	36.348	9.0)	52.408	(13.0)	0.9	(0.2)	403.011	(100.0)

Note: Numbers in parentheses represent the percentage of total water use by category.

1 Federal Component based on 1978 WAPORA Study for EPA.

2 Bulk Sales Total only reflects 0.9 mgd sold within the Service Area; doesn't include 1.5 mgd sold to Howard County.

3) WSSC use total doesn't include 1.5 mgd sold to Howard County.

TABLE G-22

FAIRFAX CITY SERVICE AREA WATER DISTRIBUTION - 1976

Month	Withdrawn Goose Cr. (mgd)	Bought From FCWA (mgd)	DISTRIBUTED TO: LCSA (mgd)	LCSA %	Herndon (mgd)	Herndon (%)	FCWA (mgd)	FCWA (%)	Fairfax City (mgd)	Fairfax City (%)
Jan	7.29	0.40	2.02	26.3	0.35	4.6	0.27	3.5	5.05	65.7
Feb	7.07	0.31	1.80	24.4	0.55	7.5	0.48	6.5	4.55	68.2
Mar	6.63	0.04	1.51	22.6	0.53	8.7	0.39	5.8	4.19	62.8
Apr	7.41	0.34	1.93	24.9	0.69	8.9	0.62	8.0	4.51	58.2
May	7.47	0.29	1.77	22.8	0.88	11.3	0.63	8.1	4.48	57.7
Jun	8.51	0.49	2.21	24.6	0.97	10.8	0.68	7.6	5.14	57.1
Jul	8.04	0.20	1.90	23.1	1.01	12.3	0.59	7.2	4.74	57.6
Aug	8.13	0.46	2.05	23.9	1.07	12.5	0.80	9.3	4.67	54.4
Sep	7.97	0.33	1.63	19.6	1.11	13.4	0.63	7.6	4.93	59.4
Oct	6.69	0.77	1.42	19.0	1.04	13.9	0.59	7.9	4.41	59.1
Nov	6.97	0.85	1.60	20.5	1.40	17.9	0.71	9.1	4.11	52.6
Dec	7.88	0.71	1.58	18.4	1.40	16.3	0.57	6.6	5.04	58.7
AVG	7.51	0.43	1.79	22.5	0.92	211.6	0.58	7.3	4.65	58.6

TABLE G-23

FAIRFAX CITY SERVICE AREA
WATER USE BY CATEGORY - 1976
(mgd)

Jurisdiction	Single-Family	Multi-Family	Commercial/ Industrial	Government/ Institutional	Federal [1]	Unaccounted	Bulk Sales [2]	Total
City of Fairfax*	1.727 (37.2)	0.806 (17.3)	0.511 (11.0)	0.190 (4.1)	0.005 (0.1)	1.410 (30.3)	0 (0)	4.649 (100.0)
Loudoun County Sanitation Authority**	1.328 (68.4)	0.073 (3.8)	0.207 (10.7)	0 (0)	0 (0)	0.332 (17.1)	0 (0)	1.940 (100.0)
Town of Herndon	0.410 (40.6)	0.316 (31.3)	0.131 (13.0)	0 (0)	0 (0)	0.153 (15.1)	0 (0)	1.010 (100.0)
Total***	3.465 (45.6)	1.195 (15.7)	0.849 (11.2)	0.190 (2.5)	0.005 (0.1)	1.895 (24.9)	0 (0)	7.599 (100.0)

Note: Numbers in parentheses represent the percentage of total water use by category.

[1]Federal Component Based on 1978 WAPORA Study for EPA.
[2]Bulk sales represent sales within the service area for miscellaneous use.

*Percentage of unaccounted water is high due to the fact that the entire Goose Creek Treatment Plant/Transmission System Losses are attributed to the Fairfax City Service Area. The actual percentage of unaccounted water is 16.3 percent, which was based on the total water produced at the plant and not the water used in the City. The unaccounted water also contains 0.21 mgd water used at the treatment plant.

**Comprised of 1.785 mgd purchased water plus 0.155 mgd from storage.

***Includes groundwater added to Service Area by Herndon and LCSA Storage water but does not include water sold to the FCWA.

Loudoun County Sanitation Authority

The Loudoun County Sanitation Authority (LCSA) is a self-supporting agency that was created by the Loudoun County Board of Supervisors under the Virginia Water and Sewer Authority Act. The portion of the County in which the LCSA operates is the lower Broad Run area. Based on discussions with the LCSA and information provided on water use, it was possible to disaggregate 1976 water use to the specific water use categories. The results of this effort are presented in Table G-23.

Town of Herndon

The Town of Herndon is located on the western edge of Fairfax County and, through its Department of Public Works, purchases water from Fairfax City on wholesale basis. As indicated in Table G-22, the Town of Herndon bought approximately 0.92 mgd from Fairfax City and received an additional ten percent from groundwater sources. Because categorical water use records are not maintained by the Department, the director of public works estimated use to be 72 percent residential, 13 percent commercial/industrial and 15 percent unaccounted. Assuming that multi-family use is 80 percent of single family use and knowing that there were 3000 single family units and 1500 apartment units in the town, a breakdown of water use was undertaken. The results of these assumptions are indicated in Table G-23. The total water used in each of the user categories for the Fairfax City Water Service Area is presented in Table G-23. The estimates of water use include the groundwater sources but do not reflect water sold to the FCWA.

PRINCE WILLIAM COUNTY WATER SERVICE AREA

The Prince William County Water Service Area is an aggregation of several water supply agencies that are geographically situated within Prince William County. Six areas are discussed as contributing to the public system water use in Prince William County. They are: The City of Manassas, the City of Manassas Park, the Greater Manassas Sanitary District, the Quantico Marine Base, the Town of Quantico, and an aggregation of twelve small public well systems.

City of Manassas

The City of Manassas has as its chief source of supply Lake Manassas, which is located on Broad Run. In addition to the Broad Run source, six wells with a combined capacity of about 1.0 mgd are used as a reserve supply. Water is also provided to the Greater Manassas Sanitary District while the City of Manassas Park receives water on an emergency basis only. With the aid of information furnished by the director of public works and based on similarities to other areas, water use breakdowns were determined and are presented in Table G-24. The commercial/industrial category includes water use by the large user, International Business Machines, of approximately 0.20 mgd.

City of Manassas Park

The City of Manassas Park obtains water from groundwater sources on a continuous basis. Under emergency conditions, water can be obtained from the City of Manassas and the Greater Manassas Sanitary District. The 1976 water use as recorded by the City amounted to about 0.29 mgd. The amount of water used by the several categories is presented in Table G-24.

TABLE G-24

PRINCE WILLIAM COUNTY SERVICE AREA
WATER USE BY CATEGORY - 1976
(mgd)

Jurisdiction	Single-Family	Multi-Family	Commercial/ Industrial	Government/ Institutional	Federal	Unaccounted	Bulk Sales	Total
City of Manassas	0.648 (41.4)	0.170 (10.9)	0.568 (36.3)	0.079 (5.0)	0 (0)	0.100 (6.4)	0 (0)	1.565 (100.0)
City of Manassas Park	0.23 (79.3)	0 (0)	0.03 (10.3)	0 (0)	0 (0)	0.03 (10.3)	0 (0)	0.29 (100.0)
Greater Manassas Sanitary District	1.14 (61.3)	0.29 (15.6)	0.14 (7.5)	0.05 (2.7)	0 (0)	0.24 (12.9)	0 (0)	1.86 (100.0)
Quantico Marine Base	0.001 (0.03)	0 (0)	0.001 (0.03)	0 (0)	2.464 (84.94)	0.435 (15.0)	0 (0)	2.901 (100.0)
Town of Quantico	0.005 (10.0)	0.021 (42.0)	0.019 (38.0)	0 (0)	0 (0)	0.005 (10.0)	0 (0)	0.050 (100.0)
Community Well Systems	0.200 (76.9)	0 (0)	0.020 (7.7)	0.006 (2.3)	0 (0)	0.034 (13.1)	0 (0)	0.260 (100.0)
Total	2.224 (32.1)	0.481 (6.9)	0.778 (11.2)	0.135 (2.0)	2.464 (35.6)	0.844 (12.2)	0 (0)	6.926 (100.0)

Note: Numbers in parentheses represent the percentage of total water use by category.

Greater Manassas Sanitary District

The Greater Manassas Sanitary District (GMSD) buys, sells, and distributes water to the Yorkshire Sanitary District as well as the GMSD. The principal source of water is groundwater wells, but water is also bought from the City of Manassas, FCWA, and the Yorkshire Sanitary District. The GMSD area recorded water use of approximately 1.6 mgd in fiscal year 1976, with almost 80 percent distributed to the GMSD. Table G-24 presents information on water use by category for the GMSD.

Quantico Marine Base

The Quantico Marine Base Department of Public Works, under the Assistant Chief of Staff in the Facilities Department, is the supply agency that serves both the Quantico Marine Base and the Town of Quantico. Several surface water impoundments satisfy the demands of the area. The 1700 million gallon Lunga Reservoir is situated on Beaverdam Run which has an average daily flow of 4.65 mgd. Chopawamsic Creek, with an average daily flow of 9.0 mgd, also has a reservoir situated on it. Breckenridge Reservoir has a capacity of 450 million gallons and, by means of a 20 inch pipeline, 5.20 mgd can be pumped from Lunga Reservoir to Breckenridge. Located downstream of Breckenridge Reservoir is the 5 million gallon capacity Gray Reservoir. In 1976, the Department of Public Works processed about 2.95 mgd and sold .05 mgd to the Town of Quantico. As the base is a Federal installation, the majority of the water used is attributed to the government/institutional category. This also makes the Marine Base the large user in the area, responsible for 85 percent of the total use. Water use by category for the Marine Base is presented in Table G-24.

Town of Quantico

The Department of Public Works is responsible for the distribution and operation of the Town's facilities. Based on 1976 account records, water use by category was determined and is presented in Table G-24. Large water users in the Town of Quantico are a laundry and a laundromat. Together these, two businesses use over 13,000 gallons per day or 26 percent of the total average water use.

Community Well Systems

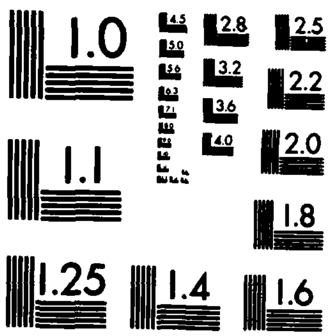
Information on the several community systems that comprise this category was obtained from the Virginia Department of Public Health and is included in Table G-25. These systems are wholly independent and, in the case of the small utilities and public service corporations, were organized as legal entities to serve the area residents. Since records on water use by category were not available, several assumptions were made as to types of use and quantities. The resulting total water use by category is indicated in Table G-24 which also presents the Prince William County Water Service Area total use by category.

LOUDOUN COUNTY WATER SERVICE AREA

The Loudoun County Water Service Area is the second of three water service areas defined as an aggregation of small water suppliers. The water suppliers aggregated into this water service area are presented in Table G-26 and include the Town of Leesburg Department of Public Works, four supply agencies receiving water from springs, and six agencies withdrawing water from wells. All the public supply agencies located in

AD-A134 159 METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY 2/5
APPENDIX G NON-STRUCTURAL STUDIES(U) CORPS OF ENGINEERS
BALTIMORE MD BALTIMORE DISTRICT SEP 83 MWA-83-P-APP-G

UNCLASSIFIED F/G 13/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Loudoun County are in the Loudoun County Water Service Area except the Loudoun County Sanitation Authority, which is supplied by the Fairfax City Water Service Area.

Town of Leesburg

The Town of Leesburg Department of Public Works was set up under authority of the Commonwealth of Virginia Code. The Town provides water for 5500 people, which is approximately 50 percent of the total amount on public systems. The Town of Leesburg pumps from several groundwater wells. In 1979, the Town began construction of a Potomac intake and water treatment plant. This project was completed in 1982. Because the monthly pumping records did not categorize water use, several assumptions were made as to meter use, water use by category, and similarity to other areas. These assumptions resulted in the breadown of water use by category presented in Table G-27. There are several large users in the area, but combined, they account for less than four percent of the total water use.

Well and Spring Systems

The majority of the public water systems presented in Table G-26 are owned and operated by towns. The legal basis for the town systems is the Virginia Code. The consumer organization of Aldie was created by and for the residents of Aldie to furnish water to that area. The systems belonging to Foxcroft School and Notre Dame Academy were organized by their respective school boards. Coleman Gore, owner of Potomac Farms, sells water to residents of the immediate area through the Potomac Farms distribution system. Since water is sold to the general public, these systems are considered public water systems by the Virginia Department of Health. Because records were not maintained, water use by category was based on several assumptions. The principal assumption dealt with the predominance of residential use in the area. The 1976 total water use by category for the Loudoun County Water Service Area is presented in Table G-27.

CHARLES COUNTY WATER SERVICE AREA

The third area examined as an aggregation of various supply agencies, the Charles County Water Service Area consists of the Public Works Departments of Charles County, Indian Head, and La Plata. Water is provided to these areas either through groundwater wells or man-made lakes.

Charles County Department of Public Works

Four residential communities are within the Charles County Department of Public Works. In 1976, a total of six wells and four distribution systems processed about 1.2 mgd for the communities of Waldorf, Spring Valley, Avon Crest, and Clifton-on-the-Potomac. Based on monthly pumping records and use categories maintained by the Charles County Department of Public Works and on the DPW estimate of unaccounted water, the water use for the various categories was developed and is shown in Table G-28.

Indian Head Department of Public Works

This agency is part of the local government and supplies water only to this community. Supplied by three wells, Indian Head used approximately 0.26 mgd in 1976 based on monthly production records. The Indian Head Department of Public Works maintains

TABLE G-25

PRINCE WILLIAM COUNTY
COMMUNITY WELL SYSTEMS

System	Estimated Population	Source	Ownership	Treatment
Bull Run Mountain	500	Wells	Bull Run Mtn. Dev. Corp.	--
Evergreen Country Club	100	Well	Evergreen Farms Water Corp.	--
Gainesville Acres	80	Wells	Gainesville Utilities	--
Lakeview Estates	350	Wells	Gainesville Utilities	--
Linton Hall School	300	Wells	Linton Hall School	--
Oak Ridge Estates	250	Wells	Oak Ridge Service Corp.	--
Occoquan Forest	200	Well	Utilities, Inc.	IR,C
Road Camp #26	70	Well	Commonwealth of Virginia	--
Somers Farm	100	Wells	Gainesville Utilities	--
Bradford Lowe Trailer Park	150	Well	Forest Grove Service Corp.	--
Independent Hill	400 Res. & Emp.	Wells	Prince William Cy. School Board	--
Algonquin Hills	--	Well	Mitchell Shell	--

*IR,C = Iron Removal, Chlorination

TABLE G-26

LOUDOUN COUNTY WATER SERVICE AREA SYSTEMS

System	Estimated Population	1970 Census	Source	Ownership	Treatment*
Aldie	150	100	Spring	Consumers	--
Foxcroft School	250 Students & Faculty	--	Wells	School	--
Hamilton	900	502	Wells	Town	IR,C
Hillsboro	135	135	Spring	Town	--
Leesburg	5,500	4,821	Wells	Town	C
Lovettsville	185	185	Wells	Town	IR,C
Middleburg	850	833	Wells	Town	--
Notre Dame Academy	140 Students & Faculty	--	Wells	N. D. Academy	--
Purcellville	2,100	1,775	Spring	Town	C
Potomac Farms	80	--	Well	Coleman Gore	--
Round Hill	600	581	Spring	Town	C

*IR = Iron Removal
C = Chlorination

TABLE G-27

LOUDOUN COUNTY SERVICE AREA
WATER USE BY CATEGORY - 1976
(mgd)

Jurisdiction	Single-Family	Multi-Family	Commercial/ Industrial	Government/ Institutional	Federal[1]	Unaccounted	Bulk Sales	Total
Town of Leesburg	0.532 (63.2)	0.058 (6.9)	0.110 (13.1)	0.018 (2.1)	0.006 (0.7)	0.118 (14.0)	0 (0)	0.842 (100.0)
Well and Spring Systems	0.521 (64.6)	0.057 (7.0)	0.108 (13.4)	0.008 (1.0)	0 (0)	0.113 (14.0)	0 (0)	0.807 (100.0)
Total	1.053 (63.9)	0.115 (7.0)	0.218 (13.2)	0.026 (1.6)	0.006 (0.3)	0.231 (14.0)	0 (0)	1.649 (100.0)

Note: Numbers in parentheses represent the percentage of total water use by category.
[1]Federal use is attributed to the Federal Aviation Administration.

TABLE G-28

CHARLES COUNTY SERVICE AREA
WATER USE BY CATEGORY - 1976
(mgd)

Jurisdiction	Single-Family	Multi-Family	Commercial/ Industrial	Government/ Institutional	Federal	Unaccounted	Bulk Sales	Total
Charles County DPW	0.692 (57.6)	0.145 (12.1)	0.175 (14.6)	0.021 (1.7)	0 (0)	0.168 (14.0)	0 (0)	1.201 (100.0)
Indian Head DPW	0.158 (61.0)	0.011 (4.2)	0.031 (12.0)	0.025 (9.7)	0 (0)	0.034 (13.1)	0 (0)	0.259 (100.0)
Town of LaPlata	0.132 (56.6)	0.030 (12.9)	0.016 (6.9)	0.024 (10.3)	0 (0)	0.031 (13.3)	0 (0)	0.233 (100.0)
Total	0.982 (58.0)	0.186 (11.0)	0.204 (12.0)*	0.046 (2.7)*	0.042 (2.5)*	0.233 (13.8)	0 (0)	1.693 (100.0)

Note: Numbers in parentheses represent the percentage of total water use by category.

*Totals are altered to account for Federal employees within the service area.

water use records for the categories of: residential, commercial, and schools. Using this information and assumptions pertaining to number of students and multi-family units, categorical water use estimates were prepared and are listed in Table G-28. Residential use is, not unexpectedly, the single largest user of water.

Town of LaPlata

The Town of LaPlata supplies and distributes water to the Town through its Department of Public Works. The water supply is obtained from several wells and a five-acre man-made lake. Because water use records by category were not available, the director of public works estimated water use for applicable categories. The water use estimates are presented in Table G-28 along with the totals for the Water Service Area.

Water use in the Outlying Service Areas approximated 18 mgd in 1976. This represented slightly more than four percent of the MWA total. As with the Potomac users, the primary user category in the outlying areas was the residential sector accounting for almost 55 percent of the total average use. The unaccounted use category was the second largest water user with Federal water use ranking third. The water use information for the Outlying Service Areas is summarized in Table G-29.

TOTAL MWA WATER USE

Based on the information just presented for the eight water service areas, MWA public water use exceeded 420 million gallons per day (mgd) in 1976. Of this total, almost 95 percent was provided by the three major water service areas: WAD, WSSC, and FCWA. Table G-30 presents the water use estimates by category for each water service area. Again, the single-family and multi-family residential categories were the largest users combining for more than 260 mgd or 62 percent of the MWA water user. The government/institutional category averaged less than 19 mgd of water use in 1976; its 4.5 percent share of total MWA use made this category the smallest user in the MWA.

The disaggregation of water demands to major categories allowed for a presentation of MWA water use as well as an indication of the relative concentration of use among user categories for each of the water service areas. This effort indicated that in the MWA, the domestic sector (single family and multi-family) accounts for a large amount of the total water use. This fact suggests that any conservation and demand reduction plans, to be effective, should include techniques to decrease water use in the residential categories.

As the degree of desired reduction increases, the more intensive the program should become. And, as the intensity of the program heightens, perhaps the non-residential user categories may also be included. These conclusions, based on the findings presented in Table G-30, are incorporated into the determination of techniques and participants included in the various conservation scenarios presented in the following sections.

WATER REDUCTION MEASURES

Prior to developing programs to decrease water use and more efficiently utilize available supplies, various alternatives were assessed as to their effectiveness and practicability in reducing water use in the MWA. By means of a survey of the many measures available to reduce water use, a range of effectiveness attributable to each of the measures was determined.

TABLE G-29

OUTLYING SERVICE AREAS
WATER USE BY CATEGORY - 1976
(mgd)

Jurisdiction	Single-Family	Multi-Family	Commercial/ Industrial	Government/ Institutional	Federal	Unaccounted	Bulk Sales	Total
Fairfax City Service Area	3.465 (45.6)	1.195 (15.7)	0.849 (11.2)	0.190 (2.5)	0.005 (0.1)	1.895 (24.9)	0 (0)	7.599 (100.0)
Prince William County Service Area	2.224 (32.1)	0.481 (6.9)	0.778 (11.2)	0.135 (2.0)	2.464 (35.6)	0.844 (12.2)	0 (0)	6.926 (100.0)
Loudoun County Service Area	1.053 (63.9)	0.115 (7.0)	0.218 (13.2)	0.026 (1.6)	0.006 (0.3)	0.231 (14.0)	0 (0)	1.649 (100.0)
Charles County Service Area	0.982 (58.0)	0.186 (11.0)	0.204 (12.0)	0.046 (2.7)	0.042 (2.5)	0.233 (13.8)	0 (0)	1.693 (100.0)
Total	7.724 (43.2)	1.977 (11.1)	2.049 (11.5)	0.397 (2.2)	2.517 (14.1)	3.203 (17.9)	0 (0)	17.867 (100.0)

Note: Numbers in parentheses represent the percentage of total water use by category.

TABLE G-30

METROPOLITAN WASHINGTON AREA
WATER USE BY CATEGORY - 1976
(mgd)

Water Service Area	Single-Family		Multi-Family		Commercial/ Industrial		Government/ Institutional		Federal		Unaccounted		Bulk Sales		Total Use	Percent of MWA
Washington Aqueduct Division	42.497	(21.8)	63.413	(32.5)	16.64	(8.5)	10.94	(5.6)	27.55	(14.1)	34.21	(17.5)	0	(0)	195.25	46.4
Washington Suburban Sanitary Commission	61.58	(44.3)	38.00	(27.3)	17.91	(12.9)	3.62	(2.6)	4.98	(3.6)	12.99	(9.3)	0	(0)	139.08	33.1
Fairfax County Water Authority	28.652	(44.4)	15.266	(23.6)	7.273	(11.3)	3.694	(5.7)	3.77	(5.8)	5.015	(7.8)	0.9	(1.4)	64.57	15.3
City of Rockville	1.924	(46.8)	0.561	(13.6)	1.068	(26.0)	0.317	(7.7)	0.048	(1.2)	0.193	(4.7)	0	(0)	4.111	1.0
Fairfax City	3.465	(45.6)	1.195	(15.7)	0.849	(11.2)	0.190	(2.5)	0.005	(0.1)	1.895	(24.9)	0	(0)	7.599	1.8
Prince William County	2.224	(32.1)	0.481	(6.9)	0.778	(11.2)	0.135	(2.0)	2.464	(35.6)	0.844	(12.2)	0	(0)	6.926	1.6
Loudoun County	1.053	(63.9)	0.115	(7.0)	0.218	(13.2)	0.026	(1.6)	0.006	(0.3)	0.231	(14.0)	0	(0)	1.649	0.4
Charles County	0.982	(58.0)	0.186	(11.0)	0.204	(12.0)	0.046	(2.7)	0.042	(2.5)	0.233	(13.8)	0	(0)	1.693	0.4
Total	142.377	(33.8)	119.217	(28.3)	44.94	(10.7)	18.968	(4.5)	38.865	(9.3)	55.611	(13.2)	0.9	(0.2)	420.878	(100.0)

Note: Numbers in parentheses represent the percentage of total water use by category.

Measures were considered that reduced water use through some sort of structural alteration to toilets, showers, or faucets. Nonstructural measures to induce water saving were also addressed such as educational programs and pricing incentives. While a number of water conserving devices were surveyed, those which were ultimately included in conservation programs were considered able to satisfy the following criteria:

-the devices should save a significant amount of water.

-the devices should be technologically and economically feasible.

-there must be a practicable means to insure their widespread use

Many measures exist which reduce water demand in all areas of use. However, the lack of any major water using industries and the large amount of residential development in the MWA were two reasons to focus primarily on conserving water in the domestic sector. The total exclusion of non-residential use, however, was not warranted; therefore, the survey of measures to reduce water use was disaggregated to Residential use and Non-Residential use.

RESIDENTIAL SECTOR

Water is used in the domestic sector for a variety of purposes that include drinking, cooking, bathing and laundering. Average indoor water use, estimated to be 70 gallons per capita per day (gpcpd) by Feldman (A Handbook of Water Conservation Devices, S.L. Feldman, Clark University NSF/RANN Grant No. Apr 76-19369, November 1977) is distributed as follows:

Function	Percentage	GPCPD
Toilet Flushing	45	31.5
Shower	18	12.6
Personal Use	12	8.4
Laundry/Dishes	20	14.0
Drinking/Cooking	5	3.5
	100	70.0

Indoor Water-Saving Devices

Numerous water-saving devices have been manufactured for all water-using appliances or fixtures in the home. Since 75 percent of total indoor use occurs within the bathroom, most of the attention given indoor water conservation was directed toward devices or appliances that reduce this type of water use. A description of several of the more acceptable and economical water-saving devices is presented for toilets, showers, faucets, clotheswashers, and dishwashers.

Toilets

The conventional toilet uses 5 to 7 gallons per flush and accounts for 45 percent of total household water use in single-family residences. This may increase to as much as 67 percent of total household use in multi-family residences (Feldman, 1977). Several of the more common devices used to reduce the amount of water associated with toilet flushing are:

1. Displacement devices,
2. Toilet dams,
3. Shallow-trap toilets,
4. Dual-cycle toilets,
5. Siphon-jet toilets,
6. Compressed air toilets, and
7. Vacuum-flush toilets.

Displacement devices are primarily for use in existing conventional tank toilets. They reduce the amount of water used to flush the toilet without decreasing the toilet's effectiveness in removing the wastes. Under laboratory conditions, two one-quart plastic bottles used to displace water achieved a 10 per cent water savings per flush or about 2.5 gpcpd (Feldman, 1977; Water Conservation and Wasteflow Reduction in the Home, W. Sharpe, Penn State, April 1974). The Washington Suburban Sanitary Commission (WSSC) realized a 4 percent minimum reduction in sewage flow after distributing displacement devices to 215,000 single-family units and 100 apartment units (Water Use and Conservation at Federal Facilities in the Washington, D.C., Metropolitan Area, for USEPA by WAPORA, Inc., Washington, D.C., April 1978).

Water-damming devices operate by sectioning off a portion of the toilet tank to reduce the volume of water available for flushing. Savings as high as 5.5 gpcpd, or about 8.0 percent of the total indoor household use, have been realized using water-damming devices (North Marin's Little Compendium of Water Saving Ideas, North Marin County Water District, California, March 1977). WSSC found a 12 to 16 percent savings over a conventional flush in multi-family dwellings and a 16 to 20 percent savings in single-family units (WAPORA, Inc., 1978). An apartment complex in Virginia realized a 20 percent water savings after installing toilet dams in its 331-unit complex (Feldman, 1977).

The shallow-trap toilet has a smaller water reservoir than the conventional toilet and can be used in new construction or to replace existing tanks. The shallow-trap toilet uses approximately 3.5 gallons per flush which results in a water savings of about 7.5 to 12.5 gpcpd, or 11 to 18 percent of the total household water use (USACE, 1976; WAPORA, Inc., 1978).

The dual-cycle toilet operates with two separate flush cycles--one for liquid wastes and one for solid wastes. Toilet modification kits are also available which can convert conventional toilets to dual cycle toilets. These toilets use about 1.25 gallons per flush for liquid wastes and 2.50 gallons per flush for solid wastes. A water savings of 17.5 to 25.0 gpcpd, or 25 to 36 percent of the total household water use, could be realized with a dual-cycle toilet.

A siphon-jet toilet siphons water from the toilet reservoir rather than emptying the tank by gravity flow. This type of flow permits a smaller water tank volume. The siphon-jet toilet uses approximately 1.0 gallon per flush and saves about 20.0 to 25.0 gpcpd, or 28 to 36 percent of the total household water use (USACE, 1976; North Marin County Water District, 1977).

The compressed-air toilet removes wastes by a combination of gravity and air propulsion of 50 to 70 pounds per square inch. The toilet uses about 0.5 gallons per flush, thus saving approximately 25 gpcpd amounting to about 36 percent of the total household water use (North Marin County Water District, 1977; Feldman, 1977).

The vacuum toilet uses about 0.5 gallons of water and 3.25 cubic feet of air for the vacuum transporting of sewage by specially-designed toilet distribution pipes and storage

tanks. This system is too expensive for installation in individual homes but seems to be cost-effective where many toilets can be operated as part of one system as in a new housing development (USACE, 1976). If the system is used, a per capita water savings of about 22 to 25 gallons could be achieved. This amounts to 30 to 36 percent of the total household water use (WAPORA, Inc., 1978; Feldman, 1977; "Vacuum-Operated Toilet Cuts High-Rise-Office Water Use 90%," ASCE, Civil Engineering, May 1973, p. 100). There are several specialty toilets available to the public, but because of their general unacceptability, they were not included in this discussion.

Showers

Normal shower flow has been estimated to be from 5 to 15 gallons per minute (gpm) for a per capita usage of about 12.6 gallons. This usage rate can be reduced through the use of flow control devices, aerators, thermostatic mixing valves, and automatic shut-off valves. Flow control devices on showerheads restrict the passage of water without affecting the quality of the shower. These devices can reduce the flow rate to 3 gpm and save about 6.3 to 9.5 gpcpd. This amounts to 9.0 to 13.6 percent of the total household water use (USACE, 1976; WAPORA, Inc., 1978). The flow control devices may consist of specially designed showerheads, plastic inserts for existing showerheads, or pipe inserts placed ahead of existing showerheads.

By mixing water with air, an aerator reduces the volume of water flowing from the showerhead and gives the appearance of a greater flow than is actually present. The aerators are available with flow rates of 1.5 to 3.0 gpm with the 3.0 gpm unit usually used for the shower. Again, a savings of 7.0 to 10.0 gpcpd, or 10 to 14 percent of the total household water use could be achieved (Feldman, 1977; WAPORA, Inc., 1978).

A special type of aerator uses compressed air to force a low water flow at a rate of 0.5 gpm through the showerhead. The system, however, requires special piping and an air compressor which makes the system available only for new construction. A savings of 10.5 to 12.0 gpcpd, or 15.0 to 17.0 percent of the total household water use could be realized by using this system (Feldman, 1977). The use of thermostatic mixing valves saves water by eliminating the warm-up time and the constant re-adjusting of the water when the temperature changes. A potential savings of 2.0 gpcpd may be achieved through the use of this device which constitutes 3.0 percent of the total household water use (WAPORA, Inc. 1978).

The automatic shut-off valve is an on/off valve installed ahead of the showerhead. These devices are usually hand, foot, or knee-operated and come with variable or fixed flow rates. Water savings have been estimated at about 6.0 gpcpd or about 9 percent of the total household water use. These devices can be preset to deliver a specific volume of water, thus reducing wasted water (Feldman, 1977; WAPORA, Inc., 1978).

Faucets

The faucets normally found in a residential unit use between 5 and 6 gpm. Various devices have been developed which will reduce these delivery rates to about 0.5 to 4.0 gpm. These devices include flow control devices, aerators, spray taps, and thermostatic mixing valves. Flow control devices deliver a constant flow rate regardless of water pressure and are incorporated into the faucet itself or "in-line" ahead of the faucet. A flow control faucet uses between 0.5 and 2.5 gpm with the latter figure the most often used. A savings of 0.5 gpcpd for each faucet employing a flow control device could be

achieved which would reduce total household water use between 0.8 and 1.6 percent (North Marin County Water District, 1977; Feldman, 1977; WAPORA, Inc., 1978).

Faucet aerators, like shower aerators, create an air-water mixture which achieves the same results as a conventional faucet. Easy to install on existing faucets, water savings are estimated to be about 0.5 gpcpd for each faucet. If aerators were to be employed on all the household sinks, total household water use could be reduced about 1.5 percent (North Marin County Water District, 1977; WAPORA, Inc., 1978).

Spray taps do not aerate the water but deliver it in a broad pattern of droplets. They are applied to bathroom and kitchen sinks in new construction and have a flow rate of 1.0 to 2.0 gpm. Water savings are estimated to be about 0.75 gpcpd per faucet which constitutes about 2 percent of total household water use (Feldman, 1977; North Marin County Water District, 1977).

The thermostatic mixing valves and automatic shut-off valves used in conjunction with bathroom and kitchen sink faucets operate in the same manner as described earlier for showers. The thermostatic mixing valves can save about 2.0 gpcpd or 3 percent of the total household water use.

Laundry and Dishwashing

The average residential unit uses approximately 20 percent of its water for laundry and dishwashing. This amounts to 14.0 gpcpd for a standard family of four (Feldman, 1977). Since most laundry and dishwashing is done by machine, knowledge of the water conserved by clotheswashers and dishwashers is essential in planning a water conservation program.

Most dishwashers use an average of 13 to 16 gallons during a 60-minute cycle. Handwashing an equal amount of dishes would use between 15 to 25 gallons, depending on technique. If the dishwasher has a cycle adjustment designed to conserve water, usage can be reduced to between 7 to 12 gallons per cycle, or an average reduction of about 35 percent. This equals a maximum savings of 7 percent in total household water use.

Use of water by clotheswashers on a regular cycle ranges from 38 to 53 gallons and from 39 to 69 gallons on a permanent press cycle. These water use figures are based on an 8 pound load, maximum fill, in a water system of 40 psi. Only recycling clotheswashers have been studied and an average water savings of 20 percent has been estimated (Feldman, 1977). This equals a 4 percent reduction in total household use. If an average family of four used commercially available water-saving clotheswashers and dishwashers an average of once a day, a water savings of 2.8 to 5.0 gpcpd, or 4 to 7 percent of the total household water use could be achieved.

Other Water-Saving Devices

There are several water conservation devices which are not directly applied to toilets, showers, or faucets. These include hot water pipe insulation and pressure reducing valves. Hot water pipe insulation saves water by retaining heated water in the distribution pipes thus reducing the waiting time for hot water when the tap is turned on. Application to both new and existing residential units is possible, and insulation can achieve a savings of 2.0 gpcpd, or 3 percent of total indoor water use (Feldman, 1977; North Marin County Water District, 1977).

Pressure-reducing valves (PRVs) are usually installed in the main water supply lines and reduce the pressure to about 50 pounds per square inch (psi). Water savings with PRVs vary dramatically due to the variance in distribution system pressure. Savings from 0 to 37 percent have been reported in tests conducted around the country (Feldman, 1977; WAPORA, Inc., 1978; Texas Water Development Board Conservation Plan, Ken Jacobs, March 1977). Based on these reported percent reductions, PRVs applied to the residential sector could result in a water savings of 0.0 to 26.0 gpcpd. Table G-31 summarizes characteristics of the indoor conservation devices discussed above.

Outdoor Water Conservation

In the MWA, outdoor water use is the primary factor responsible for seasonal variation in water use patterns. Water is used outdoors primarily for lawn and garden watering, swimming pools, and car washing. Unlike other portions of the country, the MWA does not employ irrigation devices for outdoor water use. The primary tool for outside water distribution (i.e., lawn sprinkling, carwashing) is the common garden hose. There are several water saving devices and appliances available for reducing the water used for these purposes. These water-saving devices include the following: hose attachments, timer-controlled sprinklers, and swimming pool covers.

There are several hose attachments which improve the efficiency of the water distribution and, therefore, may reduce water use. These attachments range from "pistol grip" nozzles to mechanical sprinklers at costs of $1 to $40. The actual volume of water saved through the use of these attachments has not been determined (Residential Water Conservation, Murray Milne, California Water Resources Center, Report No. 35, March 1976). Devices are also available which let one know when to water plants and lawns. They include coring tools for taking soil samples, probes which change color when water is needed, and electrical-sensing probes which determine the soil moisture using electric current. Costs range from $2 to $25 (Milne, 1976). Water savings for these devices have not been estimated.

Water can also be saved by controlling the time used for sprinkling. Automatic timers are available which allow for sprinkling on a set time basis or a set volume basis. Outdoor water savings are difficult to determine when using these devices (Milne, 1976). Costs are from $70 upwards. For households with swimming pools, water can be saved by using pool covers. Covers can be either roll-on, floatable, or hydraulic. The water savings achieved are dependent on the size of the pool and the efficiency of the pool cover. Evaporation from a 20 by 40 foot pool has been estimated at a maximum of 100 gallons per day. However, the water savings are much less (Milne, 1976).

Public Awareness Programs

In addition to the above mentioned devices, outdoor water conservation can be achieved through increasing public awareness. The primary programs used to increase awareness of personal water use habits are educational. Municipal ordinances, usually one of the stronger incentives, may also deter outdoor water use.

An educational campaign could change individual attitudes and water use habits. Such a campaign should be conducted when the public is aware of the need to reduce total water use. People are becoming more aware of water supply problems, especially during

TABLE G-31

WATER-SAVING DEVICES:
ESTIMATED INDOOR WATER USE

Device or Appliance	Water Use	(gpcpd)	(% of Total Household Water Use)	Addit'l $ Cost*	Comments*
Toilet Displacement Devices	N/A	2.5	4.0	0-6	
Toilet Damming Devices	N/A	5.5	8.0-20.0	1-6	
Dual Cycle Toilet	1.25-2.5 gpf**	17.5-25.0	25.0-36.0	4-14	Device insert
				0-65	New tank
Shallow-Trap Toilet	3.5 gpf	7.5-12.5	11.0-18.0	13-65	
Siphon-Jet Toilet	1.0 gpf	20.0-25.0	28.0-36.0	0-125	New only
Compressed Air Toilet	0.5 gpf	25.0	36.0	0-290	New only
Vacuum Toilet	0.5 gpf	22.0-25.0	30.0-36.0	Unknown	Cost-effective for large scale use
Shower Flow Control Devices	3.0 gpm	6.3-9.5	9.0-13.6	1-5	
Shower Aerators	1.5-3.0 gpm	7.0-10.0	10.0-14.0	1-5	
Compressed Aerator	0.5-1.0 gpm	10.5-12.0	15.0-17.0	200	New only
Thermostatic Mixing Valve	N/A	2.0	3.0	24-100	
Automatic Shutoff Valve	N/A	6.0	9.0	0-2	
Faucet Flow Control Devices	0.5-2.5 gpm	0.5/faucet	0.8/faucet	1-5	Modification
				10-30	New
Faucet Aerators***	2.0-3.5 gpm	0.5/faucet	0.8/faucet	1-2	
Spray Taps	1.0-2.0 gpm	0.75/faucet	1.0/faucet	20-50	New
Dishwasher	7-12 gal.	5.0	7.0	Unknown	Maximum
Clotheswasher	30-55 gal.	3.0	4.0	Unknown	Recycle-Machine
Hot Pipe Insulation	N/A	2.0	3.0	0.5/foot	Maximum
Pressure Reducing Valve	N/A	0.0-26.0	0.0-37.0	20-30	Savings vary dramatically

N.A. - not available.
* Cost of equipment only.
** Gallons per flush.
*** Source: WAPORA, Inc., 1977.

drought situations, and this is the time when education programs will work best. It has been found that a maximum reduction of 20 percent in total overall (indoor and outdoor) water use could be achieved at no cost to a household just by changing personal attitudes and water use habits. This amounts to about 14.0 gpcpd (M. Milne, 1976).

In Miami, during a water supply shortage, an educational program aimed primarily at personal habits resulted in a temporary 9 percent reduction in total water use (Social Aspects of Urban Water Conservation, Century Research Corporation, for U.S. Department of Interior, PB 214970, August 1972). In a voluntary participation program, the WSSC distributed to all its customers a kit containing water-saving devices and information on water-saving ideas. This program decreased indoor and outdoor water use by 12.0 to 20.0 percent (The Impact of Water Saving Device Installation Programs on Resource Conservation, W.E. Sharpe and P.W. Fletcher, Institute for Research on Land and Water Resources, Publication No. 98, Penn State, July 1977).

Incentive Programs

There are several programs which may induce water conservation through water-saving devices or public awareness. These programs include: 1) changes in plumbing codes, 2) full metering programs, 3) changes in price, and 4) tax deductions or subsidies. The difference between an educational campaign and a program based entirely on regulations or plumbing codes is that the former depends on the voluntary cooperation of the public while the latter would require compliance enforced through legal means. It has been estimated that savings as high as 26.4 gpcpd could be achieved by requiring the installation of water-saving devices for residential toilets, showers, and faucets (USACE, 1976). This amounts to about a 37 percent reduction in household water use.

Water savings resulting from installing meters on residential services is well documented and impressive. Studies in California have shown that from 30 to 50 percent of the household water use could be reduced by metering residential services. The cost to install a meter and box on an existing line was estimated at about $94 per service connection (North Marin County Water District, 1977). Based on statistical studies of the water use in the New York area, it was estimated that universal metering could achieve a maximum reduction of 13.5 gpcpd for 1974 water use levels. The metering program was estimated to cost approximately $154 million (USACE, 1976).

Several other studies conducted throughout the United States have shown that water demand can be reduced significantly through the use of metering. An 83 percent reduction in total water use was noted in Elizabeth City, New Jersey, in 1931 when the City went from 0 meters to 100 percent metering. Pueblo, Colorado, showed a 40 percent reduction in residential water usage after meters were installed. Other cities achieved reductions from 20 to 40 percent when going from no meters to 100 percent meters (Evaluation of the Use of Pricing as a Tool for Conserving Water, M. H. Chiogioji and E. N. Chiogioji, WRCC Report No. 2, Washington Technical Institute, Washington, D.C., November 1973).

Pricing has also been used to alter individual water-use habits. As the price of water increases, the use of water usually decreases. Reductions in water use attributable to pricing occur when there is a significant increase in price, otherwise, the consumer will adjust to a mild incease in price without conservation. Based on empirical equations developed by C. W. Howe and F. P. Linaweaver in 1967, it has been shown that for a price increase from $.20 per 1,000 gallons to $.40 per 1,000 gallons, a 10 percent

decrease in household water use was achieved. Summer sprinkling was cut in half with the same price increase. Increasing the price further to $.80 per 1,000 gallons achieved a 69 percent reduction in total household water use at the $.20 per 1,000 gallons price level (M. Chiogioji, 1973).

The American Water Works Association showed that water use decreased during a 2-year period after a significant increase in water prices. In Yuma, Arizona, rate increases of 45 and 48 percent achieved a 10 and 16 percent decrease, respectively, in water use over the 2 years following the price increase. In Kansas City, a 50 percent rate increase saved 10 percent over a 2-year period, while in New Orleans, a 70 percent rate increase created an immediate water use reduction of 6 percent (M. Chiogioji, 1973). During the first few months of experience with its newly adopted increasing block rate structure, WSSC estimated a savings of 6.5 percent for monthly billed customers (1978). As part of the MWA Water Supply Study, pricing was an alternative investigated to determine its role in influencing MWA water demands. This analysis is included as Annex G-2 and the results are summarized in the previous section on Water Pricing.

In order to achieve the voluntary installation of water-saving devices, an incentive could be offered to the homeowner or renter in the form of an increased tax deduction. This could be patterned after legislation in California which allows the homeowner to deduct up to 55 percent (not to exceed $3,000) of the cost of installing solar water heating devices (Water Conservation Reuse & Supply, J. B. Gilbert & Associates, October, 1977). An incentive program of this type could apply to additional cost which may be incurred by installing water-saving devices more efficient than those required by plumbing codes. Table G-32 presents a summary of the overall water savings achieved in different areas of the country using nonstructural modifications.

NON-RESIDENTIAL SECTOR

As stated earlier, the non-residential sector includes the government/institutional and the commerical/industrial user categories. Water conservation can be practiced in the government/institutional area in a manner similar to the residential sector. The commercial/industrial user category is limited to applying water conservation techniques to their non-productive or non-process waters. Industrial water conservation practices on the production lines are strictly process oriented and will not be discussed within this literature review. The remaining sections describe water-saving devices which may be implemented in the non-residential sector and the nonstructural programs which have been used in the non-residential sector.

Water-Saving Devices

Most of the water-saving devices described earlier for the residential sector could be implemented in the non-residential sector. There are, however, several devices which would be more adaptable to the non-residential sector. These devices include automatic flush toilets, siphon-jet urinals, and spring-and-time faucets.

The automatic flush valve toilets operate directly from the water supply line and do not require a tank. These toilets use approximately 3.5 to 4.0 gallons per flush. Most government/institutional facilities use this type of device. The siphon-jet urinal uses approximately one gallon per flush when installed with specific flush valves. This is a water savings of 50 to 75 percent over conventional urinals which require 2 to 4 gallons per flush (WAPORA, Inc. 1978). Spring-and-time faucets automatically shut off the

water supply after a set amount of time. The faucets must be held to keep the water flowing so unattended taps are eliminated. The flow times are variable, therefore, the water savings for these types of faucets have not been estimated.

Water Conservation Programs

Several programs directed toward water conservation have been conducted in the government/institutional area. The programs consist primarily of the installation of water-saving devices with supplemental education of individuals. Pricing and metering incentive programs have not been reported in the literature. In a study at Pennsylvania State University, one dormitory was equipped with several water-saving devices throughout and one dormitory was used as a control. An overall water savings of about 40 percent was achieved in the dormitory using water-saving devices (Sharpe, 1977).

At the National Naval Medical Center in Bethesda, Maryland, a 5-year program aimed at the reduction of water use resulted in a 14.7 percent water savings. The program consisted primarily of the installation of water-saving devices in both old and new construction. The Department of Defense initiated a water conservation program at Fort McNair, Fort Meyer, and Cameron Station, which created a 15 percent reduction in water use during the summer of 1977. The program consisted of the replacement of worn-out fixtures with new water-saving fixtures. A water conservation program conducted at the National Institute of Health achieved a water savings by applying devices to a total of 70 hot and cold faucets. Spray taps delivering 0.5 gpm were installed on 70 faucets, and a water savings of 87 percent hot water and 27 percent cold water was achieved in a 5-month period (WAPORA, Inc., 1978).

DEVELOPMENT OF WATER CONSERVATION SCENARIOS

Water conservation and demand reduction techniques have been shown to decrease water use to varying degrees. The degree of reduction, however, is dependent upon the elements incorporated into a water reduction program. To assess potential effects of conservation on the baseline scenario (most probable) water demands, five water conservation scenarios were designed. These scenarios varied the water user participation rates, the rates of effectiveness attributable to the various demand reduction techniques, and the number and type of demand reduction devices included. Each of these scenarios, through the use of the MWA water demand model (discussed in Appendix D - Supplies, Demands, and Deficits), was then incorporated into the baseline water demands resulting in decreased levels of projected water use. The purpose of this section is to present the baseline water demands, the composition of the several conservation scenarios, and the water savings associated with each of the scenarios.

BASELINE WATER DEMANDS

Together with population, households, and employment estimates, water use by category was incorporated into the MWA water demand model to develop a baseline water demand projection. This baseline scenario represented the most probable water demand situation for the time frame under study --1980 to 2030. Included in these water demand projections were anticipated results of actions taken prior to 1980 to decrease water use. In the late 1970's, legislation was enacted by the District of Columbia, the State of Maryland, and the Commonwealth of Virginia which changed their respective plumbing regulations. Essentially, these revised plumbing codes require the installation and use of water-saving fixtures in all new residential (single-family, multi-family) and non-

TABLE G-32

WATER SAVINGS THROUGH NONSTRUCTURAL PROGRAMS AND INCENTIVES

PROGRAM	LOCATION	WATER SAVINGS (PERCENT)	COMMENTS
Educational Campaign	California	20.0	
	Miami, Fl.	9.0	During a water supply crisis
	WSSC (MD)	12.0-20.0	With use of water saving devices
Regulations*	New York	13.0-37.0	Projected indoor use
Metering*	California	30.0-50.0	
	Elizabeth City, NJ	83.0	0% to 100% metered
	Pueblo, CO	40.0	
	Salisbury, MD**	25.0	1960, 100% metered
	Akron, Ohio**	32.0	1920, 0% to 100% metered
Pricing*	Kansas City	10.0***	50% rate increase
	New Orleans	6.0	70% rate increase

*Incentives to achieve a desired change in water use.

**Source: M. Chiogioji, 1973.

***Over the 2 years following price increase.

residential (commercial/industrial, government/institutional, Federal) construction. These regulations are contained in the legislation which is referenced in Figures G-12 through G-14 of this appendix. Table G-33 presents the maximum allowable water use for the various fixtures addressed in the several plumbing codes. It is these regulations, or their effects on water use, which were accounted for in the baseline water demand scenario.

Based on the water-saving characteristics of the fixtures listed in Table G-33, assumptions as to percent reduction for residential and non-residential use were made. It was assumed that the water-using devices now required for toilets, showers, and faucets in new residential construction would result in reductions in water use related to these functions of 15 percent, 10.5 percent, and 2 percent, respectively. Therefore, indoor water use in the new residential category was assumed to be reduced by 27.5 percent.

TABLE G-33

MAXIMUM WATER USE RATES FOR FIXTURES

FIXTURE	DISTRICT OF COLUMBIA	STATE OF MARYLAND	COMMONWEALTH OF VIRGINIA
Water Closet (Gal/Flush)	3.5	3.5	3.5
Flushometers (Gal/Flush)	–	–	3.5
Urinals (Gal/Flush)	3.0	3.0	3.0
Shower Heads (Gal/Minute)	3.0	3.0	3.0
Lavatory and Kitchen Sink Faucets (Gal/Minute)	4.0	4.0	4.0

Source: WAPORA, Inc., 1978.

The revised plumbing standards also require the installation of water-saving fixtures in all new construction of non-residential facilities. Applying several assumptions regarding water use to the non-residential use categories, an estimate of water saved subsequent to construction was developed. The assumptions used in this process are indicated below.

a. One toilet per 25 employees (estimate based on state requirements) each toilet saving 1.5 to 3.5 gpf,

b. One faucet per 25 employees (estimate based on state requirements) saving 1.0 to 2.0 gpm,

c. 2.7 flushes per day per employee (estimate based on information in 1978 WAPORA Report),

d. 0.5 minute wash per flush per day per employee for a total of 1.35 minutes per day per employee, and

e. A negligible reduction in water use due to showers.

These assumptions resulted in estimates of water saved per employee ranging from 9.45 gallons to 14.85 gallons per day.

Taking current unit use per employee which was developed for each water service area, a percentage savings was estimated for the non-residential water use categories. The average percent reduction in commercial/industrial water use was estimated to be about 19 percent while a 15 percent reduction in water use for the Federal and government/institutional categories was estimated to result from the installation and use of water-saving devices in all newly constructed facilities. The baseline water demand projections resulting from the various assumptions of residential and non-residential use are presented in Table G-34. These baseline demands represented a minimum reduction in water use. Each of the following water conservation scenarios included this minimum conservation effort and built upon it to achieve increasing degrees of water reduction.

WATER CONSERVATION SCENARIO ONE

Water Conservation Scenario One is the least intensive of the five conservation scenarios that were formulated; it was oriented strictly toward indoor residential water use. Included in Scenario One were the demand reduction techniques of the baseline scenario as well as an increased emphasis on water conservation in new residential construction. Additionally, Scenario One addressed indoor water use in residential structures existing at the commencement of the planning period. The techniques and water savings associated with this particular water conservation scenario are presented below.

a. Baseline Scenario reduction devices;

b. Pressure Reducing Valves - were assumed to achieve a 2 percent reduction in indoor water use for 25 percent of the new residential users from 1980 to 2030;

c. Pipe Insulation - was assumed to achieve a 2 percent reduction for 100 percent of all new residential users for the entire 1980-2030 period;

d. Clotheswashers and Dishwashers - were assumed to result in a 2 percent reduction in indoor water use for 100 percent of all new residential users from the year 2000 through the year 2030;

e. Toilet Modifications - were assumed to achieve a 16 percent reduction in water use for 5 percent of all existing residential users in 1980; for 30 percent of existing users in 1990; for 50 percent of existing users in 2000; for 53 percent of existing users in 2010; for 57 percent of existing users in 2020; and for 60 percent of existing users in 2030;

f. Shower Modifications - were assumed to result in a reduction of 9 percent for 2.5 percent of all existing residential users in 1980; for 15 percent of existing users in 1990; for 25 percent of existing users in 2000; for 26 percent of existing users in 2010; for 28 percent of existing users in 2020; and for 30 percent of existing users in 2030;

g. Nonstructural Modifications - This technique was assumed to address new and The participation rates are as follows:

Year	Single Family	Multi-Family
1980	20 percent of new and existing	5 percent of new and existing
1990	40 percent of new and existing	10 percent of new and existing
2000-2030	50 percent of new and existing	20 percent of new and existing

Through implementation of this water conservation scenario, projected MWA baseline water use could be reduced approximately 7 percent by the year 2030. Table G-35 presents projected water demands for the eight water service areas resulting from the reduced levels of use indicated by Scenario One.

WATER CONSERVATION SCENARIO TWO

Since each succeeding conservation program built upon the techniques contained in the preceding programs, Water Conservation Scenario Two was slightly more comprehensive than Scenario One. Scenario Two added to the elements of Scenario One by assuming reductions in outdoor residential water use. Through the implementation of an educational campaign to reduce water use, nonstructural modifications were assumed to reduce outdoor water use for 100 percent of all residential users from 1980-2030. Outdoor water use by single-family residents was assumed to decrease by 20 percent while the multi-family residential users were assumed to achieve a 10 percent reduction in outdoor water use. The techniques contained in Water Conservation Scenario Two are as follows:

a. Baseline scenario reduction devices;

b. Reduction techniques outlined as Water Conservation Scenario One, directed toward indoor residential water use;

c. Education campaign to reduce outdoor water use by single-family (20 percent) and multi-family (10 percent) residential users.

The projected demands resulting from adoption of the techniques in Water Conservation Scenario Two are presented in Table G-36. The demands represented by Scenario Two are approximately 8 percent less than the baseline water demands.

TABLE G-34

BASELINE SCENARIO
MWA AVERAGE ANNUAL WATER DEMANDS*
(mgd)

WATER SERVICE AREA	1980	1990	2000	2010	2020	2030
WAD	196	218	230	235	242	247
WSSC	145	187	215	242	267	288
FCWA	71	89	104	117	135	151
ROCKVILLE	5	5	5	6	6	6
FAIRFAX CITY	10	14	16	19	23	26
PRINCE WILLIAM COUNTY	7	9	12	14	17	20
LOUDOUN COUNTY	2	3	5	8	11	16
CHARLES COUNTY	3	5	6	8	10	11
TOTAL MWA	439	530	592	649	710	765*

* Regional totals may not agree with column summations due to rounding.

WATER CONSERVATION SCENARIO THREE

Water Conservation Scenario Three was oriented toward reducing water use in the non-residential user categories. Through an educational campaign to conserve water, employees and management would be made aware of their respective personal and outdoor water use habits. As a result of these educational programs, a 10 percent reduction in indoor and outdoor non-residential water use was assumed. The various reduction measures of Water Conservation Scenario Three are as follows:

a. Baseline scenario reduction devices;

b. Reduction techniques outlined as Water Conservation Scenario One directed at indoor residential water use;

c. Reduction techniques of Water Conservation Scenario Two directed at outdoor residential water use;

d. Educational campaigns to reduce indoor and outdoor non-residential water use.

The results of implementing these reduction techniques to decrease the baseline demands are indicated in Table G-37. The water use estimates represented as Water Conservation Scenario Three are approximately 11 percent less than the baseline water demands presented in Table G-34.

WATER CONSERVATION SCENARIO FOUR

Water Conservation Scenario Four addressed water use represented by the unaccounted category. The unaccounted category represents water that is not charged for by the various utilities. This category includes water not accounted for due to inaccurate meter readings, water used for municipal purposes, water used for system maintenance, (blow-off, line flushing), water lost as a result of system leakage, and deterioration. Scenario Four concentrated on reducing water lost through system leakage. The percent listed as unaccounted water in each water service area was reduced to a percent assumed to represent a "tight" system. For those water service areas currently exhibiting an unaccounted water use percentage between 9 and 15 percent, the percent unaccounted was reduced to 9 percent. This situation occurred in the following water service areas: WSSC, FCWA, Prince William County, Loudoun County, and Charles County.

The WAD and Fairfax City Water Service Areas exhibited unaccounted water use greater than 15 percent of the total water distributed. The water records for the WAD Water Service Area indicated that only about 4.1 percent of the unaccounted water could be saved. Therefore, the percentage of unaccounted water in this system was reduced to 13.4 percent.

The Fairfax City Water Service Area exhibited a relatively large percentage of unaccounted water. Of the 1.895 mgd that was unaccounted water, only 0.670 mgd was assumed saved as a result of improved system efficiency. Therefore, the percent unaccounted was reduced from 24.9 percent to 16.1 percent. Because the Rockville Water Service Area system had an unaccounted percentage of less than 9 percent, the system was considered to be "tight" and the percentage was not reduced. The elements in Water Conservation Scenario Four consist of the following:

TABLE G-35

WATER CONSERVATION SCENARIO ONE
MWA AVERAGE ANNUAL DEMANDS*
(mgd)

WATER SERVICE AREA	1980	1990	2000	2010	2020	2030
WAD	196	210	216	220	226	231
WSSC	145	179	201	226	248	267
FCWA	71	86	98	110	126	141
ROCKVILLE	5	5	5	5	5	5
FAIRFAX CITY	10	13	15	18	21	24
PRINCE WILLIAM COUNTY	7	9	11	13	16	19
LOUDOUN COUNTY	2	3	5	7	11	15
CHARLES COUNTY	3	4	5	8	9	10
TOTAL MWA	439	509	556	608	663	713

* Regional totals may not agree with column summations due to rounding.

TABLE G-36

WATER CONSERVATION SCENARIO TWO
MWA AVERAGE ANNUAL DEMANDS*
(mgd)

WATER SERVICE AREA	1980	1990	2000	2010	2020	2030
WAD	196	209	214	219	224	229
WSSC	145	177	199	223	245	264
FCWA	71	85	97	109	125	140
ROCKVILLE	5	5	5	5	5	5
FAIRFAX CITY	10	13	15	17	21	24
PRINCE WILLIAM COUNTY	7	9	11	13	16	19
LOUDOUN COUNTY	2	3	5	7	10	15
CHARLES COUNTY	3	4	5	8	9	10
TOTAL MWA	439	504	551	602	656	706

* Regional totals may not agree with column summations due to rounding.

a. Baseline scenario reduction devices;

b. Scenario One techniques directed at indoor residential water use;

c. Scenario Two techniques directed at outdoor residential water use;

d. Scenario Three techniques directed at indoor and outdoor non-residential water use; and

e. Actions such as leak detection surveys and closer system monitoring to reduce the amount of water lost.

Results of enacting Scenario Four to decrease the baseline water demands are presented in Table G-38. The water use estimates represented by this scenario are approximately 87 percent of the year 2030 baseline water demands.

WATER CONSERVATION SCENARIO FIVE

Representing the greatest level of potential reduction for the MWA, Scenario Five was formulated by assuming installation of the most efficient water-using devices in new residential construction, an intensive device installation program oriented toward existing residences, reductions in outdoor residential water use, a reduction in unaccounted water, and reductions in indoor and outdoor non-residential water use. The many techniques utilized as Water Conservation Scenario Five are presented below for each of the categories involved.

1. New single-family and multi-family construction was assumed to involve installation of the following devices:

a. Toilets - through installation of a one gallon/flush Siphon-jet toilet, a 32 percent reduction in indoor water use was assumed for 100 percent of the new residential users from 1980-2030.

b. Showers - a 14 percent reduction in water use was assumed for 100 percent of the new residential users from 1980-2030 through installation of shower aerators.

c. Faucets - based on a water savings of 0.5 percent per faucet, a 2 percent reduction in indoor water use was assumed for 100 percent of the new residential users from 1980-2030.

d. Pipe insulation - this conservation measure was assumed to result in a 3 percent reduction for 100 percent of the new residential users from 1980-2030.

e. Clotheswashers - were assumed to reduce water use 4 percent for 100 percent of the new residential users from 2000-2030.

f. Dishwashers - a reduction of 7 percent for 100 percent of the new residential users was assumed from 2000-2030.

2. Existing single-family and multi-family residences were assumed to install the following device modifications:

TABLE G-37

WATER CONSERVATION SCENARIO THREE
MWA AVERAGE ANNUAL DEMANDS*
(mgd)

WATER SERVICE AREA	1980	1990	2000	2010	2020	2030
WAD	196	200	206	210	215	219
WSSC	145	173	193	217	238	256
FCWA	71	82	93	105	120	134
ROCKVILLE	5	5	5	5	5	5
FAIRFAX CITY	10	13	15	17	20	23
PRINCE WILLIAM COUNTY	7	8	11	13	15	18
LOUDOUN COUNTY	2	3	4	7	10	14
CHARLES COUNTY	3	4	5	7	9	10
TOTAL MWA	439	488	532	581	632	680

*Regional totals may not agree with column summations due to rounding.

TABLE G-38

WATER CONSERVATION SCENARIO FOUR
MWA AVERAGE ANNUAL DEMANDS*
(mgd)

WATER SERVICE AREA	1980	1990	2000	2010	2020	2030
WAD	196	191	196	200	205	209
WSSC	145	172	193	216	238	255
FCWA	71	82	93	105	120	134
ROCKVILLE	5	5	5	5	5	5
FAIRFAX CITY	10	11	13	15	18	21
PRINCE WILLIAM COUNTY	7	8	10	12	15	18
LOUDOUN COUNTY	2	3	4	6	10	14
CHARLES COUNTY	3	4	5	7	8	9
TOTAL MWA	439	475	519	567	618	664

* Regional totals may not agree with column summations due to rounding.

a. Toilet dams - installation of these modifications was assumed to result in reductions of 18 percent for:

-10 percent of existing users in 1980;
-40 percent of existing users in 1990;
-50 percent of existing users in 2000;
-60 percent of existing users in 2010;
-70 percent of existing users in 2020;
-80 percent of existing users in 2030.

b. Showerheads - a 12 percent reduction in water use was assumed for:

-5 percent of existing users in 1980;
-23 percent of existing users in 1990;
-37 percent of existing users in 2000;
-39 percent of existing users in 2010;
-42 percent of existing users in 2020;
-45 percent of existing users in 2030.

3. Indoor and outdoor water use in both new and existing residences was assumed to be reduced through an educational program oriented toward nonstructural modifications. The following water use reductions were assumed:

a) Indoor - water use in new and existing residences was assumed to be reduced 2 percent for:

-30 percent of single-family users and 7.5 percent of multi-family users in 1980;
-60 percent of single-family users and 15 percent of multi-family users in 1990;
-75 percent of single-family users and 30 percent of multi-family users from 2000 to 2030.

b) Outdoor - water use in new and existing residences (same as Scenario Two) was assumed to decrease by:

-20 percent for all new and existing single-family residences from 1980 to 2030,
-10 percent for all new and existing multi-family residences from 1980 to 2030.

4. Unaccounted water was assumed to be reduced to the same degree as described in Scenario Four. The water service areas involved are as follows:

WAD - reduced to 13.4 percent,
WSSC - reduced to 9.0 percent,
FCWA - reduced to 9.0 percent,
Rockville - no reduction,
Fairfax City - reduced to 16.1 percent,
Prince William - reduced to 9.0 percent,
Loudoun - reduced to 9.0 percent,
Charles - reduced to 9.0 percent.

5. Indoor and outdoor non-residential water use was assumed to be reduced through structural and nonstructural means.

Structural - installation and use of the devices presented in the baseline scenario:

-toilets saving 1.5 to 3.5 gallons per flush,
-faucets saving 1.0 to 2.0 gallons per minute.

Nonstructural - implementation of an educational campaign to reduce total indoor and outdoor non-residential water use by 15 percent.

The development of Water Conservation Scenario Five assumed the maximum achievable reduction levels for devices as well as greater household participation rates. These assumptions led to an approximate reduction of 28 percent in the year 2030 baseline scenario demands. The effects of the imposition of Scenario Five on Baseline demands are presented in Table G-39. To summarize the baseline scenario and the five water conservation scenarios, Table G-40 is presented. This table indicates the categories addressed, the devices included in the various scenarios, and the percent reduction attributed to each of the devices. The water reductions which were projected to be achieved in the MWA by each of the five water conservation scenarios are presented in Table G-41.

WATER SERVICE AREA ANALYSIS

The water conservation scenarios just presented all reduce water use. Because of the differing composition of the water service areas, however, a scenario may be more effective in one area than in another. This section briefly discusses the applicability and effectiveness of the various scenarios in the water service areas.

Washington Aqueduet Division

A reduction in Baseline Scenario demands of approximately 7 percent was achieved by the year 2030 with the introduction of Water Conservation Scenario One. Minimal reductions approximating 7.5 percent and 11.5 percent were attributed to Scenarios Two and Three, respectively. The projected water use that resulted from enacting Scenario Four indicated that a 16 percent reduction could be achieved by the year 2030. Water Conservation Scenario Five further reduced demands to almost 75 percent of the baseline projections.

Washington Suburban Sanitary Commission

The effect of the water conservation scenarios on the Baseline Scenario demands ranged from 7 to 8 percent (Scenarios One and Two, respectively) to approximately 11 percent for both Scenarios Three and Four. This indicates that reductions aimed at residential outdoor water use achieved a minimal response. Scenario Three achieved an additional 3 percent reduction by addressing the indoor and outdoor non-residential sector. The reduction in unaccounted water attributed to Scenario Four resulted in practically no water savings due to the extremely high efficiency of the WSSC water distribution system.

Fairfax County Water Authority

Compared to the Baseline Scenario water demands, the five conservation scenarios achieved a 6 to 28 percent reduction in water demand by the year 2030. The emphasis placed on outdoor residential use by Scenario Two did not increase the percentage reduction much (from 6 percent to 7 percent) when compared to Scenario One. However, by including Scenario Three reductions in non-residential water use, an additional 4 percent reduction in water use was achieved. Because the reduction in system losses

TABLE G-39

WATER CONSERVATION SCENARIO FIVE
MWA AVERAGE ANNUAL DEMANDS*
(mgd)

WATER SERVICE AREA	1980	1990	2000	2010	2020	2030
WAD	196	179	182	183	185	186
WSSC	145	155	168	182	195	205
FCWA	71	74	82	90	100	109
ROCKVILLE	5	4	4	5	5	5
FAIRFAX CITY	10	10	11	12	14	15
PRINCE WILLIAM COUNTY	7	7	9	10	12	14
LOUDOUN COUNTY	2	2	3	5	7	10
CHARLES COUNTY	3	3	4	5	6	7
TOTAL MWA	439	435	462	491	522	551

* Regional totals may not agree with column summations due to rounding.

TABLE G-40

ELEMENTS OF THE
WATER CONSERVATION SCENARIOS

SCENARIO	WATER USE CATEGORIES	CONSERVATION MEASURES	PERCENT REDUCTION
Baseline	New SF and MF Residential	Toilets	15.0
		Showers	10.5
		Faucets	2.0
	New C/I	All 3 Fixtures*	19.0
	New G/I and Federal	All 3 Fixtures	15.0
One	(Baseline Plus:)	PRV's	2.0
	New SF and MF Residential	Pipe Insulation	2.0
		Clotheswasher	2.0
		Dishwasher	2.0
	Existing SF	Toilet Mod.	16.0
	and MF	Shower Mod.	9.0
	All Residential	Behavior Mod.	2.0
Two	(Scenario One Plus:)		
	All SF (Outdoor)	Behavior Mod.	20.0
	All MF (Outdoor)	Behavior Mod.	10.0
Three	(Scenario Two Plus:)		
	All C/I, G/I and Fed	Behavior Mod.	10.0
Four	(Scenario Three plus:)		
	Unaccounted	N/A	Variable
Five	New SF and MF	Siphon-Jet Toilet	32.0
		Shower Controls	14.0
		Faucet Controls	2.0
		Pipe Insulation	3.0
		Clotheswasher	4.0
		Dishwasher	7.0
		Behavior Mod.	2.0
	Existing SF and MF	Toilet Mod.	18.0
		Shower Mod.	12.0
		Behavior Mod.	2.0
	All SF (Outdoor)	Behavior Mod.	20.0
	All MF (Outdoor)	Behavior Mod.	10.0
	All C/I, G/I and Fed	Behavior Mod.	15.0
	New C/I	All 3 Fixtures*	19.0
	New G/I and Fed	All 3 Fixtures*	15.0
	Unaccounted	N/A	Variable

* The low-water-using toilets, showers, and faucets.
SF - Single-family MF - Multi-family
C/I - Commercial/Industrial G/I - Government/Institutional

TABLE G-41

SUMMARY OF CONSERVATION SCENARIO DEMANDS
1980 - 2030
(mgd)

SCENARIO	1980	1990	2000	2010	2020	2030
Baseline Scenario	439	530	592	649	710	765
Conservation Scenario One	439	509	556	608	663	713
Conservation Scenario Two	439	504	551	602	656	706
Conservation Scenario Three	439	488	532	581	632	680
Conservation Scenario Four	439	475	519	567	618	664
Conservation Scenario Five	439	435	462	491	522	551

(less than 1 percent) achieved by Scenario Four did not significantly reduce water demands, it is evident that the FCWA Water Service Area maintains an efficient distribution system.

City of Rockville

Scenario One which was a device remodeling program attained a reduction in baseline water use of approximately 6 percent in 2030. The Scenario Two reduction in outdoor residential water use, however, only resulted in an additional demand decrease of 1 percent. Scenario Three water use was further reduced 5 percent (total of 11 percent by 2030) by aiming water conservation awareness techniques at the non-residential sector. Rockville has an extremely efficient distribution system, and because the unaccounted water use was less than 9 percent, Scenario Four had no effect on water use.

City of Fairfax

Through its remodeling program, Scenario One achieved a water reduction of about 7 percent when compared to the 2030 Baseline Scenario demands. Similar to the FCWA, the outdoor residential water reduction in Scenario Two hardly decreased demands resulting in a total reduction of less than 9 percent. A notable decrease in total water demand occurred when going from Scenario Three to Scenario Four. This large decrease was due to the reduction of the Fairfax City Water Service Area system losses. Because of the reduction in unaccounted water, Scenario Four demands were almost 80 percent of the Baseline Scenario demands in 2030. As expected, Scenario Five created the greatest reduction in total baseline water demands - over 40 percent in the year 2030.

Prince William County

By the year 2030, the remodeling program of Water Conservation Scenario One resulted in a 6 percent reduction in projected Baseline Scenario water demands for the Prince William County Water Service Area. Further reductions of 1 percent attributed to the outdoor residential program in Scenario Two were minimal. With the decrease in non-residential water use achieved by Water Conservation Scenario Three, a reduction of approximately 5 percent over Scenario Two was observed for the time horizons. The increased efficiency of the Prince William County supply systems brought about by Scenario Four contributed to an additional 3 percent reduction in water use. The "high technology" scenario, as expected, attained the largest reduction in water demands.

Loudoun County

In this water service area, Scenario One achieved an approximate 7 percent reduction when compared to the 2030 Baseline Scenario demands. A better response to the outdoor residential water use program of Scenario Two was experienced in Loudoun County primarily due to the large proportion of residential use to total use. Scenario Three measures further reduced use by 3 percent (or 11 percent when compared to Baseline demands). The response of Loudoun County to the Scenario Four reduction in distribution system losses was in the range of a 4 to 5 percent decrease in Scenario Three demands. Scenario Five, the "high technology" program, achieved a 40 percent reduction in Baseline Scenario water use by the year 2030.

Charles County

The response of the Charles County Water Service Area to the alternate water conservation scenarios was similar to that of the Loudoun County Water Service Area. This was expected since both counties are on the fringe of the MWA, are similar in water use patterns, and have similar growth projections.

In addition to a 7 percent reduction resulting from Scenario One, the Scenario Two effort aimed at outdoor residential use achieved a 1 to 2 percent decrease in Baseline water use. Introduction of Scenario 3 achieved further reductions of 2 percent or a cumulative reduction of 10 percent. Scenario Four, directed at distribution system losses, resulted in an additional 5 percent decrease in water demands over Scenario Three. The effects of Scenario Five were extremely high as was expected. The percent reduction in Baseline Scenario water demands due to Scenario Five was about 40 percent in 2030.

REGIONAL ANALYSIS

By remodeling the existing residential sector and adding more water-saving devices to the new residential sector (Scenario One), a 7 percent reduction in total MWA water demand over the Baseline projections was achieved by 2030. This was decreased another 1 percent when outdoor residential water use was addressed by Conservation Scenario Two. A modest 3 to 4 percent reduction was further achieved by decreasing the non-residential water use (Scenario Three). The same magnitude of reduction was obtained by increasing distribution system efficiency through enactment of Scenario Four. Scenario Five led to a 28 percent reduction in total MWA Baseline demands by the year 2030. This was accomplished through the implementation of extensive water-saving programs directed at all categories of water use. Figure G-17 illustrates the MWA Baseline Scenario water demands and the response of the MWA baseline demands to the five water conservation scenarios.

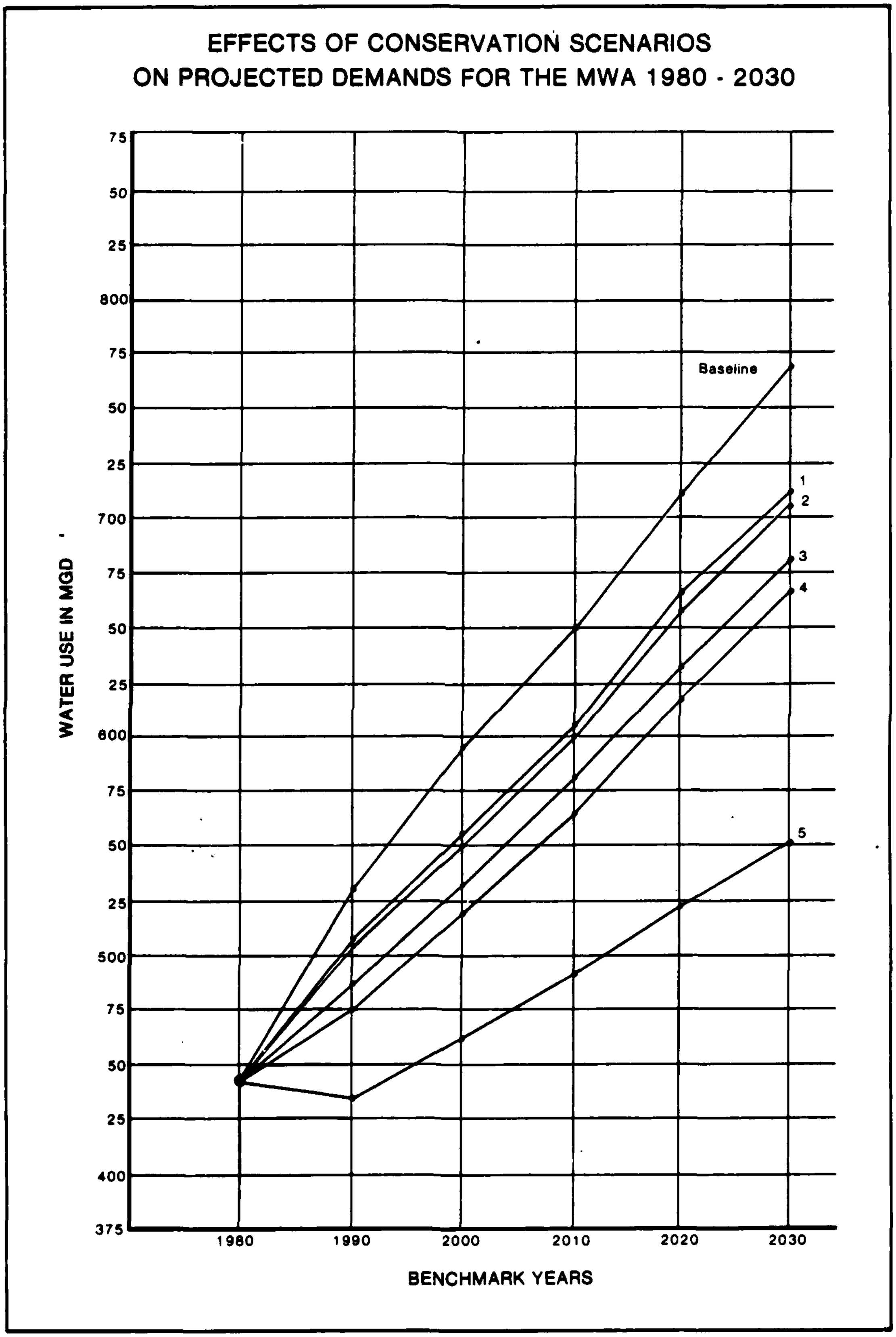
PRESENTATION OF COSTS

The water conservation scenarios were designed to achieve various levels of reduction in projected Baseline Scenario water demands. The maximum reduction achieved by the five scenarios ranged from a low of about 7 percent to a high of approximately 28 percent. Preliminary analysis resulted in the retention of Scenarios One, Three and Five for consideration in the early-action phase of the study. Preliminary costs were then developed for these conservation scenarios. It is the intent of this section to present the cost data for the water service areas and for the region as a whole. Costs presented here were developed by the consultant and are in 1977 dollars. During the course of the early-action phase costs were updated to December 1978 cost levels. These costs are found in Appendix B - Formulation, Assessment, and Evaluation of Plans.

COSTS OF SCENARIO ONE

Water Conservation Scenario One was designed to reduce water use through the implementation of a device installation program and some type of nonstructural program. Costs of these programs, then, had to reflect the costs of the techniques themselves. The unit costs associated with each conservation technique were determined from interviews with local distributors, literature surveys, and personal experience and are displayed in Table G-42. Based on known costs incurred by the WSSC for educational programs, the budget for nonstructural modifications for the other water service areas

FIGURE G-17


EFFECTS OF CONSERVATION SCENARIOS
ON PROJECTED DEMANDS FOR THE MWA 1980 - 2030
WATER USE IN MGD
375
400
25
50
75
500
25
50
75
600
25
50
75
700
25
50
75
800
25
50
75
Baseline
1
2
3
4
5
1980
1990
2000
2010
2020
2030
BENCHMARK YEARS

was estimated to approximate $85,000 per year, with the indoor residential sector accounting for $47,000 per year. Nonstructural cost estimates are presented in Table G-43.

Total capital costs were calculated by multiplying the unit costs times the number of dwelling units (Table G-44) in each time period. For example, from 1980 to 1990, the PRVs were assumed to be used in 25 percent of the total new residential construction in the MWA at a cost of $25 per dwelling unit. The total capital cost, therefore, was (0.25) x (317,650) x ($25) = $1,985,312.50, or $198,500 per year from 1980 to 1990. A similar procedure was followed for all the conservation measures listed. Another dollar amount is also given which assumed the PRVs and Insulation were not applied in the scenario. This value indicates that from 1980 to 1990, for example, $2,065,500 per year could be saved if PRVs and Insulation were not installed. Only a maximum of one percent reduction in Baseline Scenario water demand in 2030 was achieved for the approximate 1 to 2 million dollars spent each year to install these two devices. Tables G-45 to G-52 present Scenario One costs for the service areas while Table G-53 presents MWA estimated costs.

The present worth value of the uniform series of payments, exemplified by the values given in Table G-54, was calculated using an interest rate of 6.875 percent. The total present worth of Scenario One was calculated to be about $28,268,400. This value is equal to annual payments over 50 years of $2,016,100 at 6.875 percent interest.

COSTS OF SCENARIO THREE

Achieving the projected 11 percent reduction in total MWA water use through Scenario Three would require an extensive educational campaign. The educational campaign would be directed at outdoor residential water use and at total non-residential use. It would consist primarily of the distribution of printed materials (brochures, pamphlets, newsletters) which would contain helpful hints on how to reduce water use.

The unit cost of each nonstructural modification was based on the procedure outlined for development of Scenario One costs. The nonstructural techniques aimed at the outdoor residential use would cost approximately $18,000 per year. The non-residential sector would require about $20,000 per year. The total estimated cost of Scenario Three is the cost presented earlier for Scenario One plus the cost of the nonstructural techniques. Tables G-45 through G-52 present, for each service area, the capital costs associated with implementation of the non-structural modifications contained in Water Conservation Scenario Three.

Shown in Table G-53 are the annual expenditures during each time period for Scenario Three without the PRVs and Insulation measures being implemented. As mentioned earlier, 1 to 2 million dollars per year could be saved if PRVs and Insulation were omitted from the Scenario. The percent reduction achieved by the inclusion of these two devices is a maximum of about 1 percent in 2030.

The cost analysis for Scenario Three is presented in Table G-55. At 6.875 percent interest, the present worth is $28,801,300, which equals 50 annual payments of $2,054,000 at 6.875 percent. Through exclusion of PRVs and Insulation from Scenario Three, this present worth value can be reduced by about 24 million dollars at the expense of only about one percent in water reduction. Therefore, the present worth of Scenario Three could be reduced to $4,056,600. At 6.875 percent interest, this would convert to 50 annual payments of $289,300.

TABLE G-42

UNIT COSTS OF TECHNIQUES

ITEM	USER CATEGORY	ADDITIONAL UNIT COST[1]
Pressure Reducing Valve[2]	New SF and MF	$25/dwelling unit
Pipe Insulation [3]	New SF New MF	$75/dwelling unit $38/dwelling unit
Clotheswasher[4]	New SF and MF	$0
Dishwasher[4]	New SF and MF	$0
Toilet Modification[4]	Existing SF and MF	$5/toilet/dwelling unit
Shower Modification[4]	Existing SF and MF	$2/shower/dwelling unit
Nonstructural Programs[5]	New & Existing SF and MF (Indoor)	$47,000/year

[1] Additional capital costs in 1977 dollars with increased installation costs assumed negligible.

[2] Average of data presented in Table G-31.

[3] Source: Water Conservation Reuse and Supply, J. B. Gilbert & Associates, October, 1977.

[4] Personal communication with local plumbing distributors.

[5] Total MWA Cost.

TABLE G-43

COSTS OF NONSTRUCTURAL PROGRAMS
FOR WATER SERVICE AREAS*

WATER SERVICE AREA	INDOOR RESIDENTIAL	OUTDOOR RESIDENTIAL	TOTAL NON-RESIDENTIAL	TOTAL
WAD	$14,000	$5,000	$6,000	$25,000
WSSC	15,000	5,000	5,000	25,000
FCWA	9,000	3,000	4,000	16,000
ROCKVILLE	3,000	1,000	1,000	5,000
FAIRFAX CITY	3,000	1,000	1,000	5,000
PRINCE WILLIAM COUNTY	1,000	1,000	1,000	3,000
LOUDOUN COUNTY	1,000	1,000	1,000	3,000
CHARLES COUNTY	1,000	1,000	1,000	3,000
TOTAL	$47,000	$18,000	$20,000	$85,000

*All costs are dollars per year spent; all dollars are in 1977 dollars.

TABLE G-44

NUMBER OF PROJECTED DWELLING UNITS

Water Service Area	Existing 1980	New Units Added During Time Period: 1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
WAD						
Single Family	150,319	19,232	7,817	1,541	2,439	1,069
Multi-Family	238,981	47,868	20,383	11,259	12,161	11,531
WSSC						
Single Family	240,714	81,088	63,569	62,911	59,008	41,594
Multi-Family	149,586	54,612	39,731	38,489	36,292	37,064
FCWA						
Single Family	150,185	53,745	36,953	34,490	39,253	42,551
Multi-Family	77,815	30,255	24,647	22,510	32,947	25,449
ROCKVILLE						
Single Family	12,685	1,666	21	32	32	32
Multi-Family	4,015	234	479	468	468	468
FAIRFAX CITY						
Single Family	19,029	9,502	6,231	6,842	8,721	8,848
Multi-Family	5,871	3,098	2,169	2,458	3,179	3,352
PR. WILLIAM CO.						
Single Family	13,386	5,278	11,680	9,327	11,298	12,917
Multi-Family	3,614	1,422	3,420	3,073	4,002	4,783
LOUDOUN CO.						
Single Family	3,395	2,615	4,030	5,481	7,404	9,432
Multi-Family	575	515	870	1,319	1,996	2,868
CHARLES CO.						
Single Family	5,904	5,204	3,049	7,652	4,569	3,634
Multi-Family	1,376	1,316	1,051	2,148	1,131	1,526
TOTAL MWA						
Single Family	595,617	178,330	133,350	128,176	132,724	120,077
Multi-Family	481,833	139,320	92,750	81,724	92,176	87,041
Total	1,077,450	317,650	226,100	210,000	224,900	207,118

TABLE G-45

WAD SCENARIO ONE AND THREE CAPITAL COSTS
(Dollars per year*)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
SCENARIO ONE:					
PRVs	$ 41,900	$ 17,600	$ 8,000	$ 9,100	$ 7,900
Insulation	326,100	136,100	54,300	64,500	51,800
Toilet Modifications	87,600	58,400	8,800	11,700	8,800
Shower Modifications	17,500	11,700	1,200	2,300	2,300
Nonstructural Modifications	14,000	14,000	14,000	14,000	14,000
TOTAL: With[1]	$ 487,100	$ 237,800	$ 86,300	$ 101,600	$ 84,800
TOTAL: Without[2]	$ 119,100	$ 84,100	$ 24,000	$ 28,000	$ 25,100
SCENARIO THREE:					
Nonstructural Modifications					
(Outdoor Res.)	5,000	5,000	5,000	5,000	5,000
(Non-Res.)	6,000	6,000	6,000	6,000	6,000
TOTAL: With[1]	$ 498,100	$ 248,800	$ 97,300	$ 112,600	$ 95,800
TOTAL: Without[2]	$ 130,100	$ 95,100	$ 35,000	$ 39,000	$ 36,100

* Costs in 1977 dollars.
[1] Total with PRVs and insulation.
[2] Total without PRVs and insulation.

TABLE G-46

WSSC SCENARIO ONE AND THREE CAPITAL COSTS
(Dollars per year*)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
SCENARIO ONE:					
PRVs	$ 84,800	$ 64,600	$ 63,400	$ 59,600	$ 49,200
Insulation	815,700	627,700	618,100	580,500	452,800
Toilet Modifications	87,800	58,500	8,800	11,700	8,800
Shower Modifications	17,600	11,700	1,200	2,300	2,300
Nonstructural Modifications	15,000	15,000	15,000	15,000	15,000
TOTAL: With[1]	$ 1,020,900	$ 777,500	$ 706,500	$ 669,100	$ 528,100
TOTAL: Without[2]	$ 120,400	$ 85,200	$ 25,000	$ 29,000	$ 26,100
SCENARIO THREE:					
Nonstructural Modifications					
(Outdoor Res.)	5,000	5,000	5,000	5,000	5,000
(Non-Res.)	5,000	5,000	5,000	5,000	5,000
TOTAL: With[1]	$ 1,030,900	$ 787,500	$ 716,500	$ 679,100	$ 538,100
TOTAL: Without[2]	$ 130,400	$ 95,200	$ 35,000	$ 39,000	$ 36,100

* Costs in 1977 dollars.
[1] Total with PRVs and insulation.
[2] Total without PRVs and insulation.

TABLE G-47

FCWA SCENARIO ONE AND THREE CAPITAL COSTS
(Dollars per year*)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
SCENARIO ONE:					
PRVs	$ 52,500	$ 38,500	$ 35,600	$ 45,100	$ 42,500
Insulation	518,100	370,800	344,300	419,600	415,800
Toilet Modifications	51,300	34,200	5,100	6,800	5,100
Shower Modifications	10,300	6,800	700	1,400	1,400
Nonstructural Modifications	9,000	9,000	9,000	9,000	9,000
TOTAL: With[1]	$ 641,200	$ 459,300	$ 394,700	$ 481,900	$ 473,800
TOTAL: Without[2]	$ 70,600	$ 50,000	$ 14,800	$ 17,200	$ 15,500
SCENARIO THREE:					
Nonstructural Modifications					
(Outdoor Res.)	3,000	3,000	3,000	3,000	3,000
(Non-Res.)	4,000	4,000	4,000	4,000	4,000
TOTAL: With[1]	$ 648,200	$ 466,300	$ 401,700	$ 488,900	$ 480,800
TOTAL: Without[2]	$ 77,600	$ 57,000	$ 21,800	$ 24,200	$ 22,500

* Costs in 1977 dollars.

1 Total with PRVs and insulation.
2 Total without PRVs and insulation.

TABLE G-48

ROCKVILLE SCENARIO ONE AND THREE CAPITAL COSTS
(Dollars per year*)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
SCENARIO ONE:					
PRVs	$ 1,200	$ 300	$ 300	$ 300	$ 300
Insulation	13,400	2,000	2,000	2,000	2,000
Toilet Modifications	3,800	2,500	400	500	400
Shower Modifications	800	500	100	100	100
Nonstructural Modifications	3,000	3,000	3,000	3,000	3,000
TOTAL: With[1]	$ 22,200	$ 8,300	$ 5,800	$ 5,900	$ 5,800
TOTAL: Without[2]	$ 7,600	$ 6,000	$ 3,500	$ 3,600	$ 3,500
SCENARIO THREE:					
Nonstructural Modifications					
(Outdoor Res.)	1,000	1,000	1,000	1,000	1,000
(Non-Res.)	1,000	1,000	1,000	1,000	1,000
TOTAL: With[1]	$ 24,200	$ 10,300	$ 7,800	$ 7,900	$ 7,800
TOTAL: Without[2]	$ 9,600	$ 8,000	$ 5,500	$ 5,600	$ 5,500

* Costs in 1977 dollars.
[1] Total with PRVs and insulation.
[2] Total without PRVs and insulation.

TABLE G-49

FAIRFAX CITY SCENARIO ONE AND THREE CAPITAL COSTS
(Dollars per year*)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
SCENARIO ONE:					
PRVs	$ 7,900	$ 5,300	$ 5,800	$ 7,400	$ 7,600
Insulation	83,000	55,000	60,700	77,500	79,100
Toilet Modifications	5,600	3,700	600	700	600
Shower Modifications	1,100	700	100	100	100
Nonstructural Modifications	3,000	3,000	3,000	3,000	3,000
TOTAL: With[1]	$ 100,600	$ 67,700	$ 70,200	$ 88,700	$ 90,400
TOTAL: Without[2]	$ 9,700	$ 7,400	$ 3,700	$ 3,800	$ 3,700
SCENARIO THREE:					
Nonstructural Modifications					
(Outdoor Res.)	1,000	1,000	1,000	1,000	1,000
(Non. Res.)	1,000	1,000	1,000	1,000	1,000
TOTAL: With[1]	$ 102,600	$ 69,700	$ 72,200	$ 90,700	$ 92,400
TOTAL: Without[2]	$ 11,700	$ 9,400	$ 5,700	$ 5,800	$ 5,700

* Costs in 1977 dollars.
[1] Total with PRVs and insulation.
[2] Total without PRVs and insulation.

TABLE G-50

PRINCE WILLIAM COUNTY
SCENARIO ONE AND THREE CAPITAL COSTS
(Dollars per year*)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
SCENARIO ONE:					
PRVs	$ 4,200	$ 9,400	$ 7,800	$ 9,600	$ 11,100
Insulation	45,000	100,600	81,600	99,900	115,100
Toilet Modifications	3,800	2,600	400	500	400
Shower Modifications	800	500	100	100	100
Nonstructural Modifications	1,000	1,000	1,000	1,000	1,000
TOTAL: With[1]	$ 54,800	$ 114,100	$ 90,900	$ 111,100	$ 127,700
TOTAL: Without[2]	$ 5,600	$ 4,100	$ 1,500	$ 1,600	$ 1,500
SCENARIO THREE:					
Nonstructural Modifications					
(Outdoor Res.)	1,000	1,000	1,000	1,000	1,000
(Non. Res.)	1,000	1,000	1,000	1,000	1,000
TOTAL: With[1]	$ 56,800	$ 116,100	$ 92,900	$ 113,100	$ 129,700
TOTAL: Without[2]	$ 7,600	$ 6,100	$ 3,500	$ 3,600	$ 3,500

* Costs in 1977 dollars.
[1] Total with PRVs and insulation.
[2] Total without PRVs and insulation.

TABLE G-51

LOUDOUN COUNTY
SCENARIO ONE AND THREE CAPITAL COSTS
(Dollars per year*)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
SCENARIO ONE:					
PRVs	$ 2,000	$ 3,100	$ 4,300	$ 5,900	$ 7,700
Insulation	21,600	33,500	46,100	63,100	81,600
Toilet Modifications	900	600	100	100	100
Shower Modifications	200	100	100	100	100
Nonstructural Modifications	1,000	1,000	1,000	1,000	1,000
TOTAL: With[1]	$ 25,700	$ 38,300	$ 51,600	$ 70,200	$ 90,500
TOTAL: Without[2]	$ 2,100	$ 1,700	$ 1,200	$ 1,200	$ 1,200
SCENARIO THREE:					
Nonstructural Modifications					
(Outdoor Res.)	1,000	1,000	1,000	1,000	1,000
(Non. Res.)	1,000	1,000	1,000	1,000	1,000
TOTAL: With[1]	$ 27,700	$ 40,300	$ 53,600	$ 72,200	$ 92,500
TOTAL: Without[2]	$ 4,100	$ 3,700	$ 3,200	$ 3,200	$ 3,200

* Costs in 1977 dollars.
1 Total with PRVs and insulation.
2 Total without PRVs and insulation.

TABLE G-52

CHARLES COUNTY
SCENARIO ONE AND THREE CAPITAL COSTS
(Dollars per year*)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
SCENARIO ONE:					
PRVs	$ 4,100	$ 2,600	$ 6,100	$ 3,600	$ 3,200
Insulation	44,000	26,900	65,600	38,600	33,100
Toilet Modifications	1,600	1,100	200	200	200
Shower Modifications	300	200	100	100	100
Nonstructural Modifications	1,000	1,000	1,000	1,000	1,000
TOTAL: With[1]	$ 51,000	$ 31,800	$ 73,000	$ 43,500	$ 37,600
TOTAL: Without[2]	$ 2,900	$ 2,300	$ 1,300	$ 1,300	$ 1,300
SCENARIO THREE:					
Nonstructural Modifications					
(Outdoor Res.)	1,000	1,000	1,000	1,000	1,000
(Non. Res.)	1,000	1,000	1,000	1,000	1,000
TOTAL: With[1]	$ 53,000	$ 33,800	$ 75,000	$ 45,500	$ 39,600
TOTAL: Without[2]	$ 4,900	$ 4,300	$ 3,300	$ 3,300	$ 3,300

* Costs in 1977 dollars.
[1] Total with PRVs and insulation.
[2] Total without PRVs and insulation.

TABLE G-53

SCENARIO ONE AND THREE CAPITAL COSTS FOR THE METROPOLITAN WASHINGTON AREA
(Dollars per year*)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
SCENARIO ONE:					
PRVs	$ 198,600	$ 141,400	$ 131,300	$ 140,600	$129,500
Insulation	1,866,900	1,352,600	1,272,700	1,345,700	1,231,300
Toilet Modifications	242,400	161,600	24,400	32,200	24,400
Shower Modifications	48,600	32,200	3,600	6,500	6,500
Nonstructural Modifications	47,000	47,000	47,000	47,000	47,000
TOTAL: With[1]	$2,403,500	$1,734,800	$1,479,000	$1,572,000	$1,438,700
TOTAL: Without[2]	$ 338,000	$ 240,800	$ 75,000	$ 85,700	$ 77,900
SCENARIO THREE:					
Nonstructural Modifications					
(Outdoor Res.)	18,000	18,000	18,000	18,000	18,000
(Non. Res.)	20,000	20,000	20,000	20,000	20,000
TOTAL: With[1]	$2,441,500	$1,772,800	$1,517,000	$1,610,000	$1,476,700
TOTAL: Without[2]	$ 376,000	$ 278,800	$ 113,000	$ 123,700	$ 115,900

* Costs in 1977 dollars.
1 Total with PRVs and insulation.
2 Total without PRVs and insulation.

TABLE G-54

COST ANALYSIS FOR WATER CONSERVATION SCENARIO ONE*

WATER SERVICE AREA	WITH PRVS & INSULATION		WITHOUT PRVS & INSULATION	
	Present Worth	Annual Payment	Present Worth	Annual Payment
WAD	$ 3,268,500	$ 233,100	$1,208,300	$ 86,200
WSSC	12,129,400	865,000	1,231,600	87,800
FCWA	8,030,000	572,700	724,700	51,700
ROCKVILLE	157,300	11,200	104,300	7,400
FAIRFAX CITY	1,368,200	97,600	122,000	8,700
PR. WILLIAM COUNTY	1,633,600	116,500	61,600	4,400
LOUDOUN COUNTY	905,300	64,600	31,900	2,300
CHARLES COUNTY	776,200	55,400	39,200	2,800
TOTAL MWA	$28,268,400	$2,016,100	$3,523,700	$251,300

*Calculated for a 50 year period using an interest rate of 6.875 percent and 1977 dollars. Totals may not agree with column summations due to rounding.

TABLE G-55

COST ANALYSIS FOR WATER CONSERVATION SCENARIO THREE*

WATER SERVICE AREA	WITH PRVS & INSULATION		WITHOUT PRVS & INSULATION	
	Present Worth	Annual Payment	Present Worth	Annual Payment
WAD	$ 3,438,400	$ 245,200	$1,350,200	$ 96,300
WSSC	12,256,500	874,100	1,351,800	96,400
FCWA	8,117,100	578,700	817,800	58,300
ROCKVILLE	189,500	13,500	137,700	9,800
FAIRFAX CITY	1,396,700	99,600	154,200	11,000
PR. WILLIAM COUNTY	1,661,400	118,500	97,800	7,000
LOUDOUN COUNTY	935,200	66,700	70,100	5,000
CHARLES COUNTY	806,500	57,500	76,900	5,500
TOTAL MWA	$28,801,300	$2,054,000	$4,056,600	$289,300

*Calculated for a 50 year period using an interest rate of 6.875 percent and 1977 dollars. Totals may not agree with column summations due to rounding.

COSTS OF SCENARIO FIVE

Scenario Five was developed to represent a comprehensive program that would extensively reduce water use in the MWA. Water-saving devices, non-structural modifications, and a leak detection and repair program were combined into a scenario which reduced projected baseline demands approximately 28 percent by the year 2030. The types of incentives included in Scenario Five were similar to those of Scenarios One and Three. However, the assumptions relating to user participation rates and to device efficiency differed from those of Scenarios One and Three as discussed previously.

The retrofit program aimed at toilet and shower modifications in existing residences was assumed to be implemented in conjunction with an educational campaign (and perhaps even incentives such as changes in pricing policies) to make the water user aware of water conservation. In order to have the water-saving devices included in new residential construction, it was assumed plumbing code modifications would be implemented to ensure the use of these devices. Actual use of the siphon-jet toilet and pipe insulation would require a strong, enforceable plumbing code because of the additional costs involved.

The unit costs associated with the ten water conservation techniques contained in Scenario Five are given in Table G-56. These unit costs were multiplied times the applicable units in the affected user categories. The unit costs of the water-saving devices were obtained from the literature and from local plumbing distributors. The unit costs derived for the Nonstructural Modifications were presented in Table G-43. The development of the unit costs listed in Table G-56 for the Leak Detection and Repair technique requires further explanation.

To generate the total cost of Scenario Five the expenditures involved in repairing distribution system leaks were estimated. Since a formal program aimed at stopping supply system leakage would require extensive planning and start-up and would be highly dependent on the actual distribution system and specific problems encountered, the total costs for the entire 50-year planning period were difficult to determine. However, based on information documented in the NEWS Study (Water Conservation Measures for the New York Metropolitan Area, U.S. Army Corps of Engineers, January 1976), an approximate unit cost was determined.

During 1954, the City of New York spent $346,916 to stop leaks of 62,671,000 gallons per day. This amounts to about $15.17 per million gallons in 1954, or about $65 in 1977 dollars. It was this number that was used as a rough estimate of the unit cost of a leak detection program. The unit cost of $65 per million gallons was multiplied by the total volume of water saved in the unaccounted for category. As explained earlier, not all service areas were reduced uniformly, nor were all service areas set at the same percentage of total use attributable to system leakage. It must be noted that the costs generated for the leak detection and repair program are gross estimates and were included in this analysis only to provide an idea of the total cost of the scenario.

Scenario Five capital costs were developed by the consultant using 1977 dollars. These costs are identified by service areas in Tables G-57 through G-64 and are presented for each conservation technique for each of the time periods. Table G-65 summarizes the Scenario Five costs estimated for each of the service areas.

TABLE G-56

UNIT COSTS OF SCENARIO FIVE TECHNIQUES

ITEM	USER CATEGORY	ADDITIONAL UNIT COST[1]
Siphon-Jet Toilet[2]	New SF & MF	$62.50/toilet/dwelling unit
Faucet Controls[3]	New SF & MF	$0
Clotheswasher[3]	New SF & MF	$0
Dishwasher[3]	New SF & MF	$0
Toilet Modification[3]	Existing SF and MF	$5/toilet/dwelling unit
Shower Modification[3]	Existing SF and MF	$2/shower/dwelling unit
Shower Controls[4]	New SF & MF	$5/shower/dwelling unit
Pipe Insulation[4]	New SF New MF	$75/dwelling unit $38/dwelling unit
Nonstructural Programs	New & Existing SF & MF (Indoor)	$47,000/year (MWA Regional Total)
	New & Existing SF & MF (Outdoor)	$18,000/year (MWA Regional Total)
	New Existing Non-residential	$20,000/year (MWA Regional Total)
Leak Detection & Repair[5]	Unaccounted	$65.00/million gallons saved

1 Additional capital costs in 1977 dollars with zero installation cost.
2 Average of data from Table G-31.
3 Personal communction with local plumbing distributors.
4 Source: (J.B. Gilbert & Associates, October, 1977).
5 Source: (USACE, January 1976), updated to 1977 costs based on an ENR cost index increase of 7.1 percent.

TABLE G-57

WAD SCENARIO FIVE CAPITAL COSTS
(Dollars Per Year*)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030	
Toilet Modifications	$ 116,800	$ 29,200	$ 29,200	$ 29,200	$ 29,200	
Shower Modifications	26,900	16,400	2,300	3,500	3,500	
Nonstructural Modifications						
(Indoor Res.)	14,000	14,000	14,000	14,000	14,000	*
(Outdoor Res.)	5,000	5,000	5,000	5,000	5,000	*
(Non-Residential)	6,000	6,000	6,000	6,000	6,000	
Siphon-Jet Toilet	838,800	352,500	160,000	182,500	157,500	
Shower Controls	67,100	28,200	12,800	14,600	12,600	
Insulation	326,100	136,100	54,300	64,500	51,800	
Leak Repair	225,200	5,700	4,700	5,500	5,000	
TOTAL	$1,625,900	$593,100	$288,300	$324,800	$284,600	
Total Without Leak Repair	$1,400,700	$587,400	$283,600	$319,300	$279,600	
Total Without Insulation	$1,299,800	$457,000	$234,000	$260,300	$232,800	

*Costs in 1977 dollars.

TABLE G-58

WSSC SCENARIO FIVE CAPITAL COSTS
(Dollars per year*)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
Toilet Modifications	$ 117,100	$ 29,300	$ 29,300	$ 29,300	$ 29,300
Shower Modifications	26,900	16,400	2,300	3,500	3,500
Nonstructural Modifications					
(Indoor Res.)	15,000	15,000	15,000	15,000	15,000
(Outdoor Res.)	5,000	5,000	5,000	5,000	5,000
(Non-Residential)	5,000	5,000	5,000	5,000	5,000
Siphon-Jet Toilet	1,696,300	1,291,300	1,267,500	1,191,300	983,200
Shower Controls	135,700	103,300	101,400	95,300	78,700
Insulation	815,700	627,700	618,100	580,500	452,800
Leak Repair	15,400	1,700	2,100	1,900	1,700
TOTAL	$2,832,100	$2,094,700	$2,045,700	$1,926,800	$1,574,200
Total Without Leak Repair	$2,816,700	$2,093,000	$2,043,600	$1,924,900	$1,572,500
Total Without Insulation	$2,016,400	$1,467,000	$1,427,600	$1,346,300	$1,121,400

*Costs in 1977 dollars.

TABLE G-59

FCWA SCENARIO FIVE CAPITAL COSTS
(Dollars per Year*)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
Toilet Modifications	$ 68,400	$ 17,100	$ 17,100	$ 17,100	$ 17,100
Shower Modifications	15,700	9,600	1,400	2,100	2,100
Nonstructural Modifications					
(Indoor Res.)	9,000	9,000	9,000	9,000	9,000
(Outdoor Res.)	3,000	3,000	3,000	3,000	3,000
(Non-Residential)	4,000	4,000	4,000	4,000	4,000
Siphon-Jet Toilet	1,050,000	770,000	712,500	902,500	850,000
Shower Controls	84,000	61,600	57,000	72,200	68,000
Insulation	518,100	370,800	344,300	419,600	415,800
Leak Repair	3,300	700	500	500	700
TOTAL	$1,755,500	$1,245,800	$1,148,800	$1,430,000	$1,369,700
Total Without Leak Repair	$1,752,200	$1,245,100	$1,148,300	$1,429,500	$1,369,000
Total Without Insulation	$1,237,400	$ 875,000	$ 804,500	$1,010,400	$ 953,900

*Costs in 1977 dollars.

TABLE G-60

ROCKVILLE SCENARIO FIVE CAPITAL COSTS
(Dollars Per Year *)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
Toilet Modifications	$ 5,000	$ 1,300	$ 1,300	$ 1,300	$ 1,300
Shower Modifications	1,200	700	100	200	200
Nonstructural Modifications					
(Indoor Res.)	3,000	3,000	3,000	3,000	3,000
(Outdoor Res.)	1,000	1,000	1,000	1,000	1,000
(Non-Residential)	1,000	1,000	1,000	1,000	1,000
Siphon-Jet Toilet	23,800	6,300	6,300	6,300	6,300
Shower Controls	1,900	500	500	500	500
Insulation	13,400	2,000	2,000	2,000	2,000
Leak Repair	0	0	0	0	0
TOTAL	$50,300	$15,800	$15,200	$15,300	$15,300
Total Without Leak Repair	$50,300	$15,800	$15,200	$15,300	$15,300
Total Without Insulation	$36,900	$13,800	$13,200	$13,300	$13,300

*Costs in 1977 dollars.

TABLE G-61

FAIRFAX CITY SCENARIO FIVE CAPITAL COSTS
(Dollars per year)*

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
Toilet Modifications	$ 7,500	$ 1,900	$ 1,900	$ 1,900	$ 1,900
Shower Modifications	1,700	1,000	100	200	200
Nonstructural Modifications					
(Indoor Res.)	3,000	3,000	3,000	3,000	3,000
(Outdoor Res.)	1,000	1,000	1,000	1,000	1,000
(Non-Residential)	1,000	1,000	1,000	1,000	1,000
Siphon-Jet Toilet	157,500	105,000	116,300	148,800	152,500
Shower Controls	12,600	8,400	9,300	11,900	12,200
Insulation	83,000	55,000	60,700	77,500	79,100
Leak Repair	31,700	5,000	6,000	7,700	8,000
TOTAL	$299,000	$181,300	$199,300	$253,000	$258,900
Total Without Leak Repair	$267,300	$176,300	$193,300	$245,300	$250,900
Total Without Insulation	$216,000	$126,300	$138,600	$175,500	$179,800

*Costs in 1977 dollars.

TABLE G-62

PRINCE WILLIAM COUNTY SCENARIO FIVE CAPITAL COSTS
(Dollars per year*)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
Toilet Modifications	$ 5,100	$ 1,300	$ 1,300	$ 1,300	$ 1,300
Shower Modifications	1,200	700	100	200	200
Nonstructural Modifications					
(Indoor Res.)	1,000	1,000	1,000	1,000	1,000
(Outdoor Res.)	1,000	1,000	1,000	1,000	1,000
(Non-Residential)	1,000	1,000	1,000	1,000	1,000
Siphon-Jet Toilet	83,800	188,800	155,000	191,300	221,300
Shower Controls	6,700	15,100	12,400	15,300	17,700
Insulation	45,000	100,600	81,600	99,900	115,100
Leak Repair	6,700	1,900	1,800	2,200	2,500
TOTAL	$151,500	$311,400	$255,200	$313,200	$361,100
Total Without Leak Repair	$144,800	$309,500	$253,400	$311,000	$358,600
Total Without Insulation	$106,500	$210,800	$173,600	$213,300	$246,000

*Costs in 1977 dollars

TABLE G-63

LOUDOUN COUNTY SCENARIO FIVE CAPITAL COSTS
(Dollars per year*)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
Toilet Modifications	$ 1,200	$ 300	$ 300	$ 300	$ 300
Shower Modifications	300	200	100	100	100
Nonstructural Modifications					
(Indoor Res.)	1,000	1,000	1,000	1,000	1,000
(Outdoor Res.)	1,000	1,000	1,000	1,000	1,000
(Non-Residential)	1,000	1,000	1,000	1,000	1,000
Siphon-Jet Toilet	39,100	61,300	85,000	117,500	153,800
Shower Controls	3,100	4,900	6,800	9,400	12,300
Insulation	21,600	33,500	46,100	63,100	81,600
Leak Repair	3,700	2,100	3,100	4,200	5,600
TOTAL	$72,000	$105,300	$144,400	$197,600	$256,700
Total Without Leak Repair	$68,300	$103,200	$141,300	$193,400	$251,100
Total Without Insulation	$50,400	$71,800	$98,300	$134,500	$175,100

*Costs in 1977 dollars.

TABLE G-64

CHARLES COUNTY SCENARIO FIVE CAPITAL COSTS
(Dollars per year*)

CONSERVATION MEASURES	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
Toilet Modifications	$ 2,200	$ 500	$ 500	$ 500	$ 500
Shower Modifications	500	300	100	100	100
Nonstructural Modifications					
(Indoor Res.)	1,000	1,000	1,000	1,000	1,000
(Outdoor Res.)	1,000	1,000	1,000	1,000	1,000
(Non-Residential)	1,000	1,000	1,000	1,000	1,000
Siphon-Jet Toilet	81,500	51,300	122,500	71,300	64,500
Shower Controls	6,500	4,100	9,800	5,700	5,200
Insulation	44,000	26,900	65,600	38,600	33,100
Leak Repair	5,200	1,100	2,900	1,600	1,300
TOTAL	$142,900	$87,200	$204,400	$120,800	$107,700
Total Without Leak Repair	$137,700	$86,100	$201,500	$119,200	$106,400
Total Without Insulation	$ 98,900	$60,300	$138,800	$ 82,200	$ 74,600

*Costs in 1977 dollars.

TABLE G-65

SCENARIO FIVE CAPITAL COSTS
FOR THE METROPOLITAN WASHINGTON AREA
(Dollars per year*)

CONSERVATION MEASURE	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
Toilet Modifications	$ 323,300	$ 80,900	$ 80,900	$ 80,900	$ 80,900
Shower Modifications	74,400	45,300	6,500	9,900	9,900
Nonstructural Modifications					
(Indoor Res.)	47,000	47,000	47,000	47,000	47,000
(Outdoor Res.)	18,000	18,000	18,000	18,000	18,000
(Non-Residential)	20,000	20,000	20,000	20,000	20,000
Siphon-Jet Toilet	3,970,800	2,826,500	2,625,100	2,811,500	2,589,100
Shower Controls	317,600	226,100	210,000	224,900	207,200
Insulation	1,866,900	1,352,600	1,272,700	1,345,700	1,231,300
Leak Repair	291,200	18,200	21,100	23,600	24,800
TOTAL	$6,929,200	$4,634,600	$4,301,300	$4,581,500	$4,228,200
Total Without Leak Repair	$6,638,000	$4,616,400	$4,280,200	$4,557,900	$4,203,400
Total Without Insulation	5,062,300	3,282,000	3,028,600	3,235,800	2,996,900

*Costs in 1977 dollars

Also given in Table G-65 are the dollars expended each year during the time period for Scenario Five minus the costs of the Leak Detection/Repair program and the Scenario Five costs minus the hot water pipe Insulation program costs. The cost of the scenario minus the leak repair costs are presented because of the gross cost estimation associated with the leak repair program. The scenario costs minus Insulation are given because of the low cost-effectiveness of the Insulation program.

The present worth of these costs is presented in Table G-66. The regional present worth totals $80,320,900 (1977 dollars) at 6.875 percent interest over 50 years. This converts to 50 annual payments of $5,728,200 at 6.875 percent. The regional present worth of Scenario Five without the cost estimate of the Leak Detection and Repair program is $78,123,400 in 1977 dollars. This represents an average annual expenditure of $5,571,500 per year over a 50-year period, assuming an interest rate of 6.875 percent. Scenario Five without the Insulation program has a regional present worth of $57,937,600, or $4,131,900 per year for 50 years at 6.875 percent interest. Since the Insulation program only creates a little less than one percent reduction in total MWA water demand by 2030, a savings of about 1.4 million dollars per year could be realized by omitting the program.

A summary of the cost analysis performed on the three water conservation scenarios is given in Table G-67 and Table G-68. Table G-67 presents a total dollar per dwelling unit cost for each plan. The total unit cost is based on the unit cost of each water conservation technique presented earlier.

Table G-67 summarizes the costs and expected percent reduction in total MWA water demand for the three scenarios discussed. As can be seen in the table, the present worth values range from a low of approximately 28 million dollars for Scenario One to a high of approximately 80 million dollars for Scenario Five. However, for a small increase in expected costs, Scenario Three yielded an approximate 60 percent improvement in water savings in the year 2030. If the PRV's and Insulation devices were to be omitted from the scenarios, considerable savings would be achieved with a minimal amount of water reduction lost.

EARLY-ACTION PHASE DECISIONS

Based on the projected results of implementing the five water conservation scenarios, a decision was made to eliminate some from further consideration in the development of plans during the early-action analysis of the Potomac River users. The basis for the screening of the five scenarios to two scenarios was projected reductions in baseline water use attributed to the scenarios shown in Figure G-17. Water Conservation Scenario One achieved a minimum level of reduction by emphasizing reductions in indoor residential use. Scenario Two included a program to reduce outdoor residential use which resulted in a further reduction of 1.5 percent by the year 2030 - a minimal amount at best. Because of the marginal reductions in water use credited to Scenario Two, this scenario was dropped from further consideration.

Again referring to Figure G-17, a similarity is also observed between Scenario Three and Scenario Four. The difference in the comprehensiveness of the two scenarios is attributed to the inclusion of a program in Water Conservation Scenario Four to reduce unaccounted use of water. While the projected reduction in use attributable to Scenario Four was almost 5 percent greater than Scenario Three, Scenario Four was deleted from further consideration in the formulation process. This was done because of the uncertainties related to achievement of reductions in the unaccounted category together

TABLE G-66

COST ANALYSIS FOR WATER CONSERVATION
SCENARIO FIVE*

WATER SERVICE AREA	WITH INSULATION		WITHOUT INSULATION	
	Present Worth	Annual Payment	Present Worth	Annual Payment
WAD	$10,145,400	$ 723,500	$ 8,174,200	$ 583,000
WSSC	34,093,200	2,431,400	24,282,300	1,731,700
FCWA	22,622,800	1,613,400	16,063,300	1,145,600
ROCKVILLE	364,300	26,000	297,800	21,200
FAIRFAX CITY	3,878,500	276,600	2,751,800	196,300
PR. WILLIAM COUNTY	4,532,500	323,200	3,127,000	223,000
LOUDOUN COUNTY	2,526,000	180,200	1,744,500	124,400
CHARLES COUNTY	2,158,200	153,900	1,496,700	106,700
TOTAL MWA	$80,320,900	$5,728,200	$57,937,600	$4,131,900

* Calculated for a 50 year period using an interest rate of 6.875 percent and 1977 dollars.

Totals may not agree with column summations due to rounding.

TABLE G-67

SUMMARY OF SCENARIO UNIT COSTS

SCENARIO	Single Family ($/Dwelling Unit) (New)*	Single Family ($/Dwelling Unit) (Retrofit)**	Multi-Family ($/Dwelling Unit) (New)*	Multi-Family ($/Dwelling Unit) (Retrofit)**
Scenario One	$100.55	$11.05	$63.55	$11.05
Scenario One W/O PRV's & Insulation	0.00	11.05	0.00	11.05
Scenario Three	101.00	11.50	64.00	11.50
Scenario Three W/O PRV's & Insulation	0.00	11.50	0.00	11.50
Scenario Five	211.00	11.50	174.00	11.50
Scenario Five W/O Insulation	136.00	11.50	136.00	11.50

* New dwellings assumed to have 2 toilets, 2 showers.
** Existing dwellings assumed to have 1.5 toilets, 1.5 showers.

NOTE: Nonstructural Modification Program assumed to cost approximately $1/dwelling unit was subdivided into $0.55 indoor and $0.45 outdoor.

TABLE G-68

MWA WATER CONSERVATION ANALYSIS

SCENARIO	Maximum Water Demand Reduction (YR 2030) (mgd)	(%)	Cost Analysis* Present Worth ($)	Annual** ($/Year)
Scenario One	57.20	6.8	$28,268,400	$2,016,100
Scenario One Without PRV's & Insulation	44.97	5.9	3,523,700	251,300
Scenario Three	84.60	11.2	28,794,200	2,053,500
Scenario Three Without PRV's & Insulation	77.37	10.3	4,056,600	289,300
Scenario Five	214.70	28.0	80,320,900	5,728,200
Scenario Five Without Insulation	208.92	27.2	$57,937,600	$4,131,900

* All dollars are 1977 dollars.
** Based on 365 days per year, 50 year period at 6.875 percent.

with implementation costs. Indeed, if a program was initiated, it may not prove to be cost-effective when considering the incremental reduction achieved.

One additional scenario was dropped from consideration in the early-action phase study. Water Conservation Scenario Five was designed as the most intensive of the scenarios. As such, it was based on a large rate of participation together with the maximum rate of efficiency obtainable for all the devices involved. The selection of this particular scenario would not have been a practical decision given the uncertainty associated with the higher degree of user participation and the unproven efficiency assumed for the various reduction measures. The screening of the water conservation scenarios, then, resulted in Scenarios One and Three being included with the Baseline Scenario in the analysis and development of early-action plans. For a full discussion of this plan development process during the early-action phase, refer to Appendix B - Plan Formulation, Assessment, and Evaluation.

LONG-RANGE PHASE DECISIONS

As a result of the early-action phase of the MWA Water Supply Study, several Plans for Choice were developed and presented in the 1979 Draft Progress Report on the Potomac Water Users. Based on these Plans for Choice and the supporting technical analyses, a group of local water suppliers and government officials took the initiative to form a water supply task force. The purpose of this task force was to develop and implement a coordinated regional approach to satisfy the area's existing and future water demands.

This Washington Water Supply Task Force met its objective and completed its "task" in early 1982. The objective was formally achieved when the Potomac water users convened on 22 July 1982 to officially adopt the strategy. Adoption of this regional strategy involved several actions: 1) agreement on a formula for cost-sharing the construction costs of the Little Seneca Lake project to be located in Montgomery County, Maryland, 2) agreement on a method for cost-sharing the purchase of water supply storage in the Bloomington Lake Reservoir, 3) agreement on and adoption of modifications to the Potomac Low Flow Allocation Agreement, and 4) agreement on other matters relating to successful execution of the aforementioned actions (This development in Metropolitan Washington water supply planning is discussed in detail in the Main Report and Appendix B - Formulation, Assessment and Evaluation.

What did all this local activity mean in terms of the MWA Water Supply Study? As previously discussed, the 1979 Draft Progress Report was the stimulus for the Potomac River Users agreeing to remedy the water supply situation themselves. Consequently, the baseline scenario analyzed at the start of the early-action phase was no longer appropriate for planning considerations in the long-range phase of the study. The baseline condition existing during the long-range phase now included the early-action alternatives of Bloomington Lake, Little Seneca Lake, Conservation Scenario Three, and reregulation. And the original problem that was to be examined in the long-range phase had been eliminated through the coordinated actions of the localities.

This positive development, then, dictated an approach in the long-range phase that not only differed from the approach of the early-action phase but also differed from the intended approach at the initiation of the MWA Water Supply Study. Rather than attempting to solve a problem which no longer manifested itself, the long-range phase examined the potential and feasibility of remaining alternatives to provide additional water to the area. One result of this approach was the decision to reexamine Water

Conservation Scenario Five and its potential for providing additional water, albeit, in an indirect way (demand reduction).

Based on this decision, the original costs for Scenario Five developed by the consultant were updated to October 1981 cost levels using the Engineering-News Record Construction Cost Index. This was done so as to provide a common cost basis for all the alternatives considered by the study team in the formulation process. Conservation Scenario Five capital costs updated to October 1981 price levels are presented in Table G-69. These capital costs were also converted to a present worth basis using an interest rate of 7 5/8 percent. This information is reflected in Table G-70. For a discussion of the evaluation of Conservation Scenario Five as a long-range alternative, refer to Appendix B - Formulation, Assessment, and Evaluation.

TABLE G-69

POTOMAC RIVER USERS
SCENARIO FIVE CAPITAL COSTS
SUMMARY

WATER SERVICE AREA	CAPITAL COSTS (1977 Dollars)	CAPITAL COSTS* (Oct. 1981 Dollars)
WAD:		
With[1]	$31,167,000	$42,886,000
Without[2]	24,839,000	34,179,000
WSSC:		
With	$104,735,000	$144,115,000
Without	73,787,000	101,531,000
FCWA:		
With	$69,498,000	$95,629,000
Without	48,812,000	67,165,000
ROCKVILLE:		
With	$1,119,000	$1,540,000
Without	905,000	1,245,000
TOTAL:		
With	$206,519,000	$284,170,000
Without	$148,343,000	$204,120,000

*Engineering News-Record Construction Cost Index was used to revise costs from December 1977 price levels (ENRCCI = 2669.43) to October 1981 price levels (ENRCCI = 3672.37). This resulted in an updating factor of 1.376.

[1] Represents Total Costs With Insulation Costs Included.
[2] Represents Total Costs Without Insulation Costs.

TABLE G-70

COST ANALYSIS
FOR WATER CONSERVATION SCENARIO FIVE
(October 1981 Dollars)

WATER SERVICE AREA	With Insulation Present Worth	With Insulation Annual Payment	Without Insulation Present Worth	Without Insulation Annual Payment
WAD	$19,040,900	$1,489,600	$15,155,600	$1,185,600
WSSC	43,228,600	3,381,800	30,579,600	2,392,200
FCWA	26,740,800	2,091,900	18,820,400	1,472,300
Rockville	599,600	46,900	457,900	35,800
Potomac Users:	$89,609,900	$7,010,200	$65,013,500	$5,085,900

* Based on a 50 year payback period and a 7.625% interest rate. With these factors,the factor for an Annual Payment on a Present Value (A/P) is 0.07823. This factor is applied to the present worth amounts to obtain an annual equivalent payment estimate. The resulting annual equivalent payment is then rounded to the nearest hundred dollars.

NOTE: Operation, Maintenance and Replacement Costs are assumed to be zero in this analysis.

WATER POTABILITY STUDY

INTRODUCTION

Generally speaking, past studies of the water supply for the MWA have addressed the problem from a quantity perspective rather than a water quality/potability viewpoint. Prior Corps studies in the 1960's and early 1970's were of the same view as the primary technical effort was devoted to developing an understanding of the deficits from a quantity standpoint. Water quality was considered only as it related to in-stream standards, rather than the ultimate treatability and/or potability of the water for human consumption.

With few exceptions, the early-action phase of this study was also devoted to a further assessment of the deficits and surpluses of the resource and not its potability. The principal exception to this approach was the analysis conducted regarding the potential use of the estuary. As discussed in detail in Appendix F - Structural Alternatives, treatability/potability studies were the principal thrust of that analysis.

In the 1979 Progress Report, which documented the results of the early-action phase of the study, the five Plans for Choice were all assumed to provide the consumer with a safe, potable source of water. The NAS-NAE Committee to review the MWA Water Supply Study had the following comment on the Progress Report in their 1980 report on Water for the Future of the Nation's Capital Area.

> "The important issue of potential health impacts also is not covered in the Draft Progress Report. Such impacts would be a possible consequence of different early-action water supply alternatives, because each of the five Plans of Choice presented in the report could potentially affect the quality of finished water distributed to portions of the metropolitan area. From the scant evidence in the report, the committee cannot conclude whether or not an impact would materialize and if it would be harmful or beneficial to certain areas, because no data on water quality are presented. Thus, it would be helpful if the report provided information about such matters as the relationship of recently proposed toxic substance criteria to the various alternatives and whether each alternative is capable of minimizing the production of trihalomethanes in water treatment plants and reducing the vulnerability to accidental spills of synthetic organic materials.
>
> Accordingly, three questions will illustrate the need to address the issue of drinking water quality:
>
> > Is it likely that releases of acid water from the Bloomington Reservoir could contain or release immobilized compounds or otherwise affect the quality of raw water provided to treatment plants and subsequently distributed to consumers?
> >
> > Is the quality of all the water supplied to users of the Potomac River the same, or is it likely that raw water interconnections and reregulation of finished water might result in water being distributed that has a different quality than certain users are accustomed to receiving?

> Is water quality in the Potomac River adequate for a safe supply, and will it be so during the coming half century?
>
> In planning water supplies to serve millions of people during the next 50 years, a careful assessment of quality appears to be required. The Potomac River, especially in the vicinity of Metropolitan Washington, has a questionable reputation for its quality, and questions such as these need to be addressed in view of the public's growing awareness of and insistence on the safest possible drinking water. Accordingly, the public needs to be informed about the quality of water it will receive under the different plans presented in the Draft Progress Report."

In similar fashion, the Citizens Task Force (CTF) for the MWA Study was critical of the lack of consideration given to water quality in the Progress Report. Over the course of the study, the CTF voiced strong concerns that a comprehensive examination be conducted of the health/potability aspects of the water supply problem. For a more complete presentation of the CTF's comments on this matter, the reader is referred to Annexes C-VII and C-VIII of Appendix C - Public Involvement.

Given the importance of the potability and health aspects to this or any other water supply study and the aforementioned concerns of both the technical and citizen advisory sectors, the Corps elected to reallocate some of the study resources during the long-range planning phase to a study of the treatability/potability of the existing and potential water supply sources.

It should be recognized that the time and financial resources to conduct the aforementioned study were limited and that the analyses conducted were not a detailed, comprehensive examination of all potability aspects. The purpose of this section is to describe the scope, conduct, and results of the potability study. This discussion does not address the lake and stream water quality analyses that were conducted as part of the Bloomington Lake Reformulation Study. The reader is referred to Appendix H - Bloomington Lake Reformulation Study for details on those analyses.

SCOPE AND OBJECTIVE OF STUDY

The primary objective of the water quality analysis was to compare the potability of both existing and potential MWA water supply sources under existing conditions. The analysis considered the feasibility of using the various water supply sources based on available treatment processes and the Environmental Protection Agency's most recent drinking water standards promulgated under the Safe Drinking Water Act (Public Law 93-523). Additionally, the effort included a very general discussion of potential potability problems and issues with respect to potential future changes as they might apply to the MWA water supply sources.

The level of detail of the analysis was limited to the extent necessary to prepare a relative ranking of existing and potential sources with respect to their desirability as a water supply source, under today's conditions, and to perform a general evaluation as to each source's overall potability. To fully define water quality and potability issues required a level of effort greater than was available for this study. Thus, what was attempted was an overview which was designed to surface and highlight potential problems of water quality and potability and provide a general assessment of existing and proposed sources and facilities. Even though it was clear that this approach potentially imbeded unknown bias within the results, the level of effort dictated that existing data

be used. These data were accepted and used on an "as reported" basis which meant that while small differences could be masked, significant differences and/or problems, if present, could be revealed.

CONDUCT AND DISPOSITION OF THE STUDY

Given the overall scope of the study and the time and fiscal constraints, a detailed scope of work was prepared and provided to various interested parties (NAS-NAE Review Committee, CTF and others) for information and review. Following the review and revision process, a final scope of work was negotiated with the EPA and the actual study was conducted by EPA's Technical Support Division, Office of Drinking Water in Cincinnati, Ohio. A copy of EPA's report is included as Annex G - III. The findings of the EPA study were furnished during the later stages of the long-range planning phase of the study and were considered in the preparation of the final study report. The following paragraphs provide a more detailed presentation of the EPA Study findings.

STUDY FINDINGS

As presented in the EPA report, there were differences in water supplies, treatment plants, and finished water quality. However, the results of the study did not show any situation where drinking water regulations would be violated or where a major problem in potability would occur other than some increase in costs of treatment and/or potential taste and odor complaints from consumers. Several issues such as the blending of new water supplies for both raw and finished water were found to be too complex to address in detail within the scope of the study; however, it appeared that the effect on potability of such blending would be minor. Optimum management of the overall MWA water supply system was noted as being important in order to keep any negative impacts to a minimum. To this end, close cooperation between MWA authorities in developing and implementing management strategies was considered essential. Additionally, using available computer programs to assist in the management, along with the development of needed new computer programs was judged to be an important consideration, particularly in the future as the supply problems (quantity and quality) become more complex.

Some of the more specific findings from the EPA study are summarized as follows:

(1) While the raw and finished waters showed overall differences in water quality, the differences were not strong enough to support a conclusion that the overall water qualities were significantly different. Further, the impact of these differences on water supply decisions would be of a second order of magnitude.

(2) While some plants are more flexible than others, all of the plants have adequate flexibility to compensate for anticipated quality changes in supply. Currently planned renovations will bring the WSSC Patuxent and WAD McMillan plants to a flexibility level comparable to other plants within the MWA.

(3) A quantitative assessment of the effects of blending different waters through a system of interconnections would be complex and beyond the scope of this effort.

(4) Finished water interconnections would result in only minor impacts and have limited potential for producing consumer complaints.

(5) Optimal management of the overall MWA water system would result in minimal source changes, thus reducing to a minimum problems in water quality and potability.

(6) Overall, the changes resulting from raw water interconnections should not be great enough to cause problems in treatment except for potential increased algal production leading to higher costs and possibly increased taste and odor complaints. Also, neither of the raw water interconnections (Potomac to Patuxent or Potomac to Occoquan) considered would cause violations of existing Federal, State, or local water quality standards.

(7) Any conclusions relative to the potability of treated water from the Potomac Estuary would be premature pending completion of the testing and evaluation of the results from the Potomac Estuary Experimental Water Treatment Plant. (The testing and evaluation program for the Potomac Estuary Experimental Water Treatment Plant was completed after the conclusion of the EPA analysis; results of the EEWTP program are contained in Appendix F.)

(8) Because of the difficulty in defining potability on an absolute basis, there is always a potential for an undetermined health problem to be associated with a particular water supply. The use of treated wastewater as part of the water supply increases this potential.

(9) While standards for organic materials in drinking water have recently been established, sufficient background data did not exist at the time of the EPA study to make meaningful evaluations of these parameters. Recent testing, however, indicates that the treated water is within the allowable organic standards for drinking water.

In conclusion, the existing water treatment systems were judged to be capable of providing potable water which would meet the current drinking water standards. Furthermore, the MWA water treatment plants are constructed and operated such that some future changes in raw water quality and/or standards can be accommodated with only minor process adjustments. While these conclusions are encouraging, additional actions should be taken, both to monitor and improve the drinking water quality situation. These actions would include, as a minimum, watershed protection programs upstream of existing water supply reservoirs and more intensive water quality monitoring programs throughout the raw and finished water supply systems. These types of programs would help to protect existing sources from further degradation as well as to detect water quality trends which might necessitate some corrective action. An areawide water quality monitoring network would also provide for a consistent set of data should more comprehensive evaluations be needed in the future.

REFERENCES

"A Handbook of Water Conservation Devices," by S.L. Feldman, Clark University for NSF/RANN No. APR76-19369, November 1977.

"A Methodology for Assessing Economic Risk of Water Supply Shortages," G.K. Young, R.S. Taylor and J.J. Hanks, for U.S. COE, Institute for Water Resources, # DACW31-71-C-0046, May 1972.

"A Model for Estimating Water Demands - Users Manual," M.S. Sonnen, WRE, #DACIN 84-77-C-0003, May 1977.

"A Perspective on the Washington Metropolitan Area Water Supply Program," by Dan Sheer, ICPRB, May 1977.

"A Study Concerning the Effect of the Continuing Drought on Selected California Industries," by Dunn & Bradstreet for Department of Water Resources, State of California, Sacramento, July 1977.

"An Exploratory Study of Possible Energy Savings as a Result of Water Conservation Practices," Oklahoma University, Bureau of Water Resources Research, Norman, Oklahoma, PB260-490.

"An Urban Water Conservation Conference Proceedings," California Department of Water Resources, Los Angeles, California, January 1976.

"Analysis of Water Requirements for Agricultural Irrigation in Pennsylvania," Research Publication #99, Institute for Research on Land and Water Resources, The Pennsylvania State University.

"Annual Housing Survey: 1974, Washington, D.C., Maryland, Virginia SMSA," Bureau of Census, U.S. Department of Commerce, August 1976.

"Charles County, Maryland, Financial Statements," Hoye, Graves, Bailey & Associates, 30 June 1977.

"Commercial Account Listing - CS62E," WSSC, Hyattsville, Maryland, 1976.

"Comprehensive Plan - Charles County, Maryland," Greenhourne & O'Mara, Inc., for Charles County Planning Commission, LaPlata, Maryland, December 1974.

"Conservation-Oriented Rates Plans," Washington Suburban Sanitary Commission, Hyattsville, Maryland.

"Cooperative Forecasting - Summary Report 1976," Metropolitan Washington Council of Governments, December 1976.

"Dealing With Drought--Toward Management Strategies," Anne M. Blackburn, Interstate Commission on the Potomac River Basin, General Publication 77-3, September 1977.

REFERENCES (CONT'D)

"Departmental Annual Reports 1976-1977," City of Falls Church, Virginia.

"Departmental Annual Reports 1975-1976," City of Falls Church, Virginia.

"Draft Environmental Impact Statement Concerning Proposed Potomac River Water Supply Structures," prepared by the U.S. Army Corps of Engineers, Baltimore, Maryland, December 1977.

"Economic Projections: Fairfax County, Virginia, 1975-2000," by John Pershing Associates and Fairfax County Office of Comp. Planning, Environmental and Technical Services Branch, July 1977.

"Evaluation of the Use of Pricing as a Tool for Conserving Water," M. H. Chiogioji and E. N. Chiogioji, Water Resources Research Center, Report No. 2, Washington Technical Institute, Washington, D.C., November 1973.

"Flush Test for Water Closets and Urinals," Dynamics Research and Development Corporation, Toledo, Ohio, 15 August 1977 (D-6737).

"Forecasting the Demand for Urban Water," J.J. Boland, The Johns Hopkins University, Baltimore, Maryland.

"Future Water Demands," C.W. Howe, C.S. Russell, R.A. Young and W.J. Vaughan, Resources for the Future, Inc., Washington D.C. 20036.

"Housing Units and Population in Prince George's County," The Maryland-National Capital Parks and Planning Commission, Upper Marlboro, Maryland 20870, June 1976.

"Impact Assessment: 1980, 1985, 1995 Land Use and Growth Patterns Implications of Forecast," Metro Growth Policy Program, Metropolitan Washington Council of Governments, February 1977.

"Interim Report-Urban Water Resources Methods of Reducing Peak Water Demand," NSF/RANN,APRT #19309, Clark University, Worcester, Massachusetts.

"Legal Aspects of Water Conservation in California - Background and Issues," Clifford T. Lee, Governor's Commission to Review California Water Rights Law, Staff Paper No. 3, August 1977.

"Metropolitan Washington Area Finished Water Interconnection Study," Daniel Sheer, et.al., Interstate Commission on the Potomac River Basin, Bethesda, Maryland, July 1978.

"Plumbing Fixtures and Fittings," Catalog E-77, Eljer Plumbingware, Pittsburg, Pennsylvania 15222.

"Potomac River Basin Water Supply - An Interim Report," NEWS Study, U.S. Army COE, March 1973.

"Price Variable in Residential Water Demand Models," K.E. Gibbs, WRR, Volume 14, No. 1, February 1978.

"Public Meeting Record - Potomac River Low Flow Allocation Agreement," Baltimore District, Corps of Engineers, Baltimore, Maryland.

"Report on Establishing Rates for Users of the Potomac Interceptor, Project 'C' and Blue Plains Water Pollution Control Plant - Volume I, Projected Wastewater Flows," Camp Dresser & McKee, Boston, Massachusetts, April 1974.

"Residential Water Conservation," by Murry Milne, California Water Resources Center, Report No. 35, University of California/Davis, March 1976.

"Results of the 1977 Demographic Survey of Fairfax County, Virginia," by D.W. Sheatsley, Fairfax County Office of Research and Statistics, February 1978.

"Social Aspects of Urban Water Conservation," Century Research Corporation, prepared for Office of Water Resources Research, U.S. Department of Interior, August 1972 (PB 214 970).

"Socio-Economic Impact Study of Alternative Water Supply Systems," Annex D, Volume II, Washington Metropolitan Area Water Supply Study of the Northeastern United States Water Supply Study, U.S. Army Corps of Engineers, New York, NY, November 1975.

Spray Taps - A Means of Energy and Water Conservation," A.A. Field, H&VE, September 1973, pg. 119.

"State of Texas Energy Conservation Plan - Volume I, Executive Summary," Texas Governor's Office of Energy Resources, June 1977.

"State of Texas Energy Conservation Plan - Volume II, Plan Report," Texas Governor's Office of Energy Resources, June 1977.

"State of Texas Energy Conservation Plan - Volume III, Energy Savings Calculations," Texas Governor's Office of Energy Resources, June 1977.

"The Demand for Water: Procedures and Methodologies for Projecting Water Demands in the Context of Regional and National Planning," Natural Resources/Water Series No. 3, Department of Economic and Social Affairs, United Nations, New York, 1976.

"The Impact of Water Saving Device Installations on Resource Conservation," W.E. Sharpe and P.W. Fletcher, Institute for Research on Land and Water Resources, Publication No. 98, Penn State, July 1977.

"The Optimization of Raw Water Interconnections for the Washington D.C. Metropolitan Area, Phase I, Hydrologic and Hydraulic Data," GKY & Assoc., Alexandria, Virginia, #DACW 31-78-C-0027, July 1978.

REFERENCES (CONT'D)

"The User-Manipulated Water Fixture: A New Target for Water Conservation," L.E. Flamm and S.A. Anderson, Mechanical Engineering, December 1974.

"The WRE Water Demand Model," by Water Resources Engineers, Walnut Creek, California, for U.S. Army COE, Honolulu, Hawaii, February 1977.

"Vacuum-Operated Toilet Cuts High-Rise-Office Water Use 90%," Civil Engineering - ASCE, May 1973.

"Water Conservation and Reuse in the Drought," Proceedings of the Fourth Annual Conference of the California Association of Reclamation Entities of Water, Contra Costa County Water District, June 1977.

"Water Conservation Measures for the New York Metropolitan Area," Northeastern U.S. Water Supply Study, U.S. Army Corps of Engineers, North Atlantic Division, January 1976.

"Water Conservation Task Group Report," for the Policy Committee Water Resources Policy Study by the Water Conservation Task Group, Water Resources Council, December 1977.

"Water Shortage Contingency Plan," prepared for the WSSC by the Metropolitan Washington Board of Trade, Washington, D.C., August 1977.

"Water Supply Study for Montgomery and Prince George's Counties, Maryland," for WSSC by Ecological Analysts, Inc., October 1977.

"Water Use and Conservation at Federal Facilities in the Washington, D.C. Metropolitan Area," by WAPORA, Inc. for U.S. EPA, April 1978.

ANNEX G-I

METROPOLITAN WASHINGTON

WATER SUPPLY EMERGENCY AGREEMENT

PREPARED BY METROPOLITAN WASHINGTON

COUNCIL OF GOVERNMENTS

G-I 1

Metropolitan Washington Water Supply Emergency Agreement

This Agreement, made and entered into this fifth day of December, 1979, between local governments and regional and special purpose agencies within the Metropolitan Washington Area signatory hereto,

WITNESSETH:

WHEREAS, it has been determined by the concerned governments and agencies signatory hereto that interjurisdictional cooperation and assistance among the signatories to conserve water and provide for necessary curtailment of water use and improved management of the existing water supply during emergency shortages will increase their ability within their jurisdictions; and

WHEREAS, the Potomac River Low Flow Allocation Agreement is designed to equitably allocate Potomac River water for public water supply in the Metropolitan Washington Area during Potomac River low flow conditions, but does not address reduction in use of water to prolong the capability of water supplies to provide water during such conditions; and

WHEREAS, the signatories are authorized under Federal, state, and local law to enter into such cooperative agreements for conservation and management of existing water supplies within the Metropolitan Washington Area, although it is recognized that long-range water supply planning should minimize the need of invoking water supply emergency agreements,

NOW, THEREFORE THE PARTIES HERETO DO AGREE AS FOLLOWS:

SECTION 1.00 PURPOSE

The purpose of this Agreement is to provide interjurisdictional assistance and coordination to conserve water and provide for necessary curtailment of water use during a critical water supply situation within the Metropolitan Washington Area.

SECTION 2.00 DEFINITIONS

2.10 "WATER SHORTAGE EMERGENCY": period during which the supply of available potable water is or may be limited such that special water conservation actions or water allocations are required to protect the health, safety, and welfare of the population.

2.20 "POTOMAC RIVER LOW FLOW ALLOCATION AGREEMENT": an agreement among the State of Maryland, Commonwealth of Virginia, District of Columbia, Washington Suburban Sanitary Commission, Fairfax County Water Authority, and the U.S. Army Corps of Engineers to allocate Potomac River water for public water supply in the Metropolitan Washington Area during Potomac River low flow conditions. (See Attachment A to the Agreement.)

2.30 "METROPOLITAN WASHINGTON WATER SUPPLY EMERGENCY PLAN," commonly called Water Supply Emergency Plan, (formerly called the "GUIDE WATER SUPPLY EMERGENCY IMPLEMENTATION PLAN"): a plan issued in January 1978 for necessary curtailment of water use and other emergency actions during a water shortage or outage to water suppliers, local governments, and specified government agencies of the Metropolitan Washington Area. (See Attachment B to the Agreement.)

2.40 "PERTINENT PORTION OF THE POTOMAC RIVER": the portion of the Potomac River subject of this plan is defined as the pertinent portion of the river subject of the Potomac River Low Flow Allocation Agreement.

2.50 "COORDINATOR": the Executive Director of the Metropolitan Washington Council of Governments or his designee.

2.60 "AQUEDUCT": Chief, Washington Aqueduct Division, Baltimore District, U.S. Army Corps of Engineers, or his designee.

2.70 "METROPOLITAN WASHINGTON WATER RESOURCES PLANNING BOARD": established by the local governments of the Metropolitan Washington Council of Governments with the responsibility for developing all policies, programs, and other actions for the effective implementation of water quality management planning and other water resources planning, including planning for water supply.

2.80 "SIGNATORY": parties who have executed this Agreement including water purveyors, local governments, and specified government agencies.

2.90 "WATER OUTAGE EMERGENCY": a condition in which the supply is in jeopardy of cessation; or is polluted; and in which immediate action is required by governments and agencies concerned to provide minimum necessary potable water for human consumption, to inform the public and to protect the health, safety, and welfare of the population in the area or areas affected.

SECTION 3.00 CONDITIONS FOR INITIATION

3.10 Potomac River Water Supply Emergencies

3.11 Stages of a Potomac River water supply shortage (Alert, Restriction, and Emergency stages) are defined and declared by the AQUEDUCT according to the POTOMAC RIVER LOW FLOW ALLOCATION AGREEMENT. These stages denote successively lower amounts of water supply available from the Potomac River. Parallel water shortages are contained in the WATER SUPPLY EMERGENCY PLAN with emergency procedures to be taken.

3.12 Potomac water supply emergencies other than water shortages, including finished water and water quality emergencies (possibly creating a water outage), that exist within that portion of the Metropolitan Washington Area under a SIGNATORY's authority shall be defined and declared by the SIGNATORY. All affected local governments will be immediately notified to coordinate emergency procedures.

3.13 Only Potomac River water supply emergencies within the PERTINENT PORTION OF THE POTOMAC RIVER are subject to this Agreement.

3.20 Non-Potomac River Water Supply Emergencies

3.21 Stages of non-Potomac water supply shortages are defined and declared by the SIGNATORY who supplies water to that portion of the Metropolitan Washington Area affected.

3.22 Non-Potomac water supply emergencies other than water shortages, including finished water and water quality emergencies, that exist within that portion of the Metropolitan Washington Area under a SIGNATORY's authority shall be defined and declared by the SIGNATORY.

SECTION 4.00 RESPONSIBILITIES OF THE COORDINATOR

Upon notification by the Aqueduct, the Coordinator will notify the District of Columbia Office of Emergency Preparedness of the necessary operations for the existing stage of water shortage emergency (same stages as defined in the Potomac River *Low Flow* Allocation Agreement); notify the public through the local news media, using the Local Emergency Broadcasting Procedures, of general aspects and actions called for in the critical stage as set forth in the Water Supply Emergency Plan; and provide informal monitoring and coordination of regional water conservation in response to a water shortage in accordance with the Plan.

SECTION 5.00 RESPONSIBILITIES OF THE SIGNATORIES

The SIGNATORIES have adopted or will adopt local procedures to meet water supply emergencies, and such procedures will be followed so long as they remain in effect. Nothing in this Agreement requires a local jurisdiction or agency to undertake any actions not allowed by law.

SECTION 6.00 WATER SUPPLY EMERGENCY AGREEMENTS

Any proposed amendment is not effective until approved by the majority of SIGNATORIES to this Agreement and any SIGNATORY who does not approve the amendments is not obligated under this Agreement to take any action or render any assistance required thereby.

SECTION 7.00 DURATION

This Agreement shall remain in effect until terminated by all SIGNATORIES hereto upon written notice setting forth the date of such termination. Withdrawal from this Agreement by one party hereto shall be made by thirty days written notice to all other parties but shall not terminate the Agreement among the remaining parties.

IN WITNESS WHEREOF the parties hereto have executed this Agreement as of the date first above written.

City of Alexandria, Virginia by Charles E. Beatley Jr. - Mayor
Mayor

Arlington County, Virginia by Dorothy T. Grotos
County Board Chairman

City of Bowie, Maryland by Audrey E. Scott - Mayor -
Mayor

City of College Park, Maryland by St. Clair Reeves - Mayor
Mayor

District of Columbia by M. Barry
Mayor

Arrington L. Dixon
City Council Chairman

City of Fairfax, Virginia by Frederick W. Silverthorn
Mayor

Fairfax County, Virginia by J. Herrity
Board of Supervisors Chairman

City of Falls Church, Virginia by Harold L. Miller
Mayor

City of Gaithersburg, Maryland by Bruce A. Goldensohn
Mayor and President of Council

City of Greenbelt, Maryland by Thomas X. White
City Councilman

Loudoun County, Virginia by ______________________
Board of Supervisors Chairman

City of Manassas, Virginia by ______________________

Montgomery County, Maryland by Charles W. Gilchrist
Intergovernmental Programs Coordinator
Scott Fosler
by ______________________
County Council President

Prince George's County, Maryland by Lawrence J. Hogan
County Executive

Parris N. Glendening
County Council Chairman

Prince William County, Virginia by Kathleen K. Seefeldt
Board of Supervisors Chairman

City of Rockville, Maryland by William E. Hanna Jr.
Mayor

City of Takoma Park, Maryland by ______________________

Town of Vienna, Virginia by Vincent J. Olson
Vice Mayor

Fairfax County Water Authority by Fred C. Morin
Chairman

Loudoun County Sanitation Authority by N. K. Shenn
Chairman

Washington Suburban Sanitary Commission by Jesse L. Maury
Commissioner

Metropolitan Washington Council of Governments by Martha V. Pennino
President

Arrington Dixon
Board of Directors Chairman

G-I-3

ATTACHMENT A

POTOMAC RIVER LOW FLOW ALLOCATION AGREEMENT

The Potomac River Low Flow Allocation Agreement (PLFAA) is presented in its entirety as Annex D-IV to Appendix D - Supplies, Demands, and Deficits. Also included in Appendix D is a copy of the modification to the PLFAA which was signed at ceremonies on 22 July 1982. The Metropolitan Washington Council of Governments is now reviewing the Metropolitan Washington Water Supply Emergency Agreement to determine if the 22 July 1982 PLFAA modification will necessitate changes in the 5 December 1979 Metropolitan Washington Water Supply Emergency Agreement.

ATTACHMENT B

WATER SUPPLY EMERGENCY PLAN

G-I-5

OUTLINE OF CONTENTS

WATER SUPPLY EMERGENCY PLAN

METROPOLITAN WASHINGTON AREA

OUTLINE OF CONTENTS

ANNEXES

I. INTRODUCTION

A. Purpose

1. To provide a comprehensive guide plan for necessary curtailment of water use and other emergency actions during a water shortage or outage to Water Suppliers, Local Governments, and specified government agencies of the metropolitan Washington area.

   Formulation of this plan occurred under the direction of the metropolitan Washington Water Supply Emergency Task Force (co-chaired by the Washington Suburban Sanitary Commission and the Council of Governments), and aided by the Public Safety Policy and Public Information Committees of the Council of Governments (COG). The Task Force/Committees were composed of representatives from local and state governments, water supply agencies, and regional agencies of the metropolitan Washington area. Significant contributions to various portions of the plan were provided by the Washington Suburban Sanitary Commission, the Metropolitan Washington Board of Trade, and the National Capital Planning Commission.

2. To identify the water conservation, health and protective measures to be applied by residents, businesses and private organizations in the area affected by a water outage emergency.

3. To provide for coordination, mutual support and assistance among the governments and agencies concerned with water emergencies.

4. This plan, in fulfilling its purpose, addresses:

   a. Initiation and Termination of Water Supply Critical Conditions - Section II

   b. Water Shortage Emergency Procedures - Section III

   c. Water Outage Emergency Planning - Section IV

      The water outage emergency plan addresses that extreme emergency situation in which there is an actual or imminent cessation of water supply. Because of the severity of such a condition, it is considered essential that the plan retain complete identification as an entity so that a reader, to gain full

- more -

comprehension of it, will not be required to cross reference while reading it. Therefore, certain definitions, statements of purpose and procedures may be repetitive to other portions of the overall plan.

B. Local Governmental Authority

In a water supply emergency the executives of affected and supporting jurisdictions and of the water suppliers have or will obtain the necessary legal authority to implement and enforce the emergency measures contained in this plan.

C. Public Education

1. Although not specifically a part of this plan, but essential to its successful implementation in time of water supply emergency, is the education of the public to prepare for and understand the emergency measures required.

2. Upon approval of this plan, Local Governments and Water Suppliers will initiate and continue a public education campaign to convince the public in their area of responsibility that:

   a. Water supply emergencies are possible.

   b. It is to the best interest of individuals, families and private organizations to prepare for such emergencies and to obtain in advance and maintain emergency supplies to assist themselves.

   c. Utmost care during water emergencies to prevent fires is essential.

   d. Plans and supplies for individual, family and organizational emergency hygienic measures are needed to protect health and well-being.

3. Local Governments and Water Suppliers will coordinate public education campaigns.

D. Definitions

1. <u>Metropolitan Washington Water Supply Emergency Agreement</u>: This proposed regional agreement provides interjurisdictional assistance and coordination to conserve water and provide for necessary curtailment of water use during a critial water supply situation within the Metropolitan Washington area.

2. Coordinator: The Executive Director of the Metropolitan Washington Council of Governments or his designee acting to coordinate a regional response to water supply emergencies as provided in the Metropolitan Washington Water Shortage Emergency Plan.

3. Water Shortage Emergency: A condition in which the normal supply of potable water from one or more water suppliers is or may be limited to the extent that special water conservation actions or water allocations from available sources are required to protect the health, safety and welfare of the population in the area affected.

4. Alert Stage: A stage of preparedness for a water supply shortage requiring increased surveillance of a potential critical condition and warnings given of the possible shortage (see Section II.B.1.a.(1)).

5. Restriction Stage: A stage of preparedness for an existing water supply shortage requiring voluntary curtailment of nonessential water use (see Section II.B.1.a.(1)).

6. Emergency Stage: A stage of preparedness for an existing critical water supply shortage (possibly leading to a water outage emergency) requiring mandatory curtailment of nonessential water use (see Section II.B.1.a.(1)).

7. Water Outage Emergency: A condition in which the supply of water from one or more water suppliers has ceased, or is in jeopardy of cessation; or is polluted; and in which immediate action is required by governments and agencies concerned to provide minimum necessary potable water for human consumption, to inform the public and to protect the health, safety and welfare of the population in the area or areas affected.

8. Water Suppliers/Distributors: Those special purpose agencies and facilities responsible for providing treated water to jurisdictions within the metropolitan Washington area.

Washington Aqueduct Division, Baltimore District
U.S. Army Corps of Engineers (Supplier)
District of Columbia (Distributor)
Arlington County, Virginia (Distributor)
Washington Suburban Sanitary Commission (Supplier/Distributor)
City of Falls Church, Virginia (Distributor)
Fairfax County Water Authority (Supplier/Distributor)
Virginia American Water Company (Alexandria and portions of Prince William County) (Distributor)
City of Bowie, Maryland (Supplier/Distributor)

City of Rockville, Maryland (Supplier/Distributor)
City of Fairfax, Virginia (Supplier/Distributor)
Loudoun County, Virginia (Distributor)
City of Manassas, Virginia (Supplier/Distributor)

9. Aqueduct: Chief, Washington Aqueduct Division, Baltimore District, U.S. Army Corps of Engineers, or his designee acting to declare water shortage stages of the Potomac River as provided in the Potomac River Low Flow Allocation Agreement.

10. Major Water User: Any user consuming more than 1,000 gallons per day.

11. River District Hydrologist: Hydrologist or his designee within the River District Office of the National Weather Service of the National Oceanic and Atmospheric Administration responsible for short- and long-range Potomac River flow and weather forecasts.

12. Metropolitan Washington Board of Trade: Metropolitan Washington business development and coordinating body to notify and coordinate local business water conservation measures possibly required during a water supply emergency.

13. U.S. General Services Administration: Agency responsible for operations and maintenance of many Federal facilities. The General Services Administration will act upon notification during a water supply critical condition to implement its own detailed emergency plan and will notify other Federal installations to implement their own emergency plans.

14. U.S. Civil Service Commission: Responsible for coordinating certain activities of many Federal installations. The Commission will act upon notification by the U.S. General Services Administration (GSA) during a water supply critical condition to implement its own detailed emergency plan and will notify other Federal installations within its responsibility (all of those not notified directly by GSA) to implement their own emergency plans.

15. Emergency Operating Centers (EOC): Facilities established and activated by Local Governments, Water Suppliers, and State civil defense/emergency services agencies, acting to facilitate communication (notification) and coordination during various emergencies including water supply emergencies.

16. District of Columbia Office of Emergency Preparedness: The Emergency Operating Center (EOC) of the District of

Columbia. This DC/EOP has extensive resources of emergency preparedness equipment and personnel. The DC/EOP and the District of Columbia Department of Environmental Services would be contacted by the Coordinator (as provided in the Metropolitan Washington Water Supply Emergency Plan) to notify affected Local Governments and Water Suppliers of a Potomac River water supply Emergency.

17. Water Emergency Supply Point: A local water distribution facility comprising one or more water transport vehicles (tank trucks or tank trailers) situated at a location convenient to residents affected by a Water Outage Emergency and from which local residents can obtain potable water in their own hand-carried containers sufficient to meet minimum essential quantities of ½ gallon of water per day per individual for drinking and cooking.

Under conditions visualized by this plan, Water Emergency Supply Points will be established by Local Governments in coordination with Water Suppliers throughout the area affected by a Water Outage Emergency at such places as public schools, fire stations or other suitable locations, utilizing suitable equipment available from local government sources, commercial sources, adjacent jurisdictions and State and Federal resources made available to assist in the emergency.

18. Washington Area Warning Alert System (WAWAS): That element of the National Warning System established by the Defense Civil Preparedness Agency to serve the Washington metropolitan area. The WAWAS comprises a network of civil defense warning sirens and a communications network which links the emergency preparedness and public safety elements of local governments and certain State and Federal agencies for transmission of warning messages and emergency information and for interjurisdictional coordination of emergency operations. The WAWAS communications network consists of:

a. The Area Communications Circuit (GP 2200), a "hot loop" of dedicated telephone circuits linking State emergency operating centers (i.e., District of Columbia, Maryland, Virginia), local emergency operating centers civil defense agencies and public safety elements (i.e., Police and Fire/Rescue headquarters), and certain Federal agencies and installations (e.g., General Services Administration, National Weather Service Washington Forecast Office, Military District of Washington, Fort Meade, Fort Belvoir, and Andrews Air Force Base).

b. The Channel G Radio, a system which serves as a backup to the Area Communication Circuit.

The Net Control for both the Area Communications Circuit and Channel G Radio is maintained by the Defense Civil Preparedness Agency/U.S. Army Communications Command Region Two Warning Center located at the Federal Regional Center, Olney, Maryland.

19. Local Emergency Broadcast Procedure (LEBP): The procedure established by local governments in the Washington metropolitan area and the local broadcast industry to provide for the transmission by local radio and TV stations of emergency information and instructions to alert residents of the area of peacetime natural or man-made disasters. The LEBP locally institutes the operational provisions of the national Emergency Broadcast System.

20. Potomac River Low Flow Allocation Agreement: An agreement between the State of Maryland, Commonwealth of Virginia, District of Columbia, Washington Suburban Sanitary Commission, Fairfax County Water Authority, and the United States Government to allocate Potomac River water for public water supply in the Metropolitan Washington Area during Potomac River low flow conditions.

II. INITIATION AND TERMINATION OF WATER SUPPLY CRITICAL CONDITIONS

A. General

1. The emergency planning delineated by this plan addresses a distinction in water supply emergencies that is important from a preparedness standpoint. The gradual decline in water availability, characteristics of a raw water supply shortage can be handled with increasingly stringent water conservation and provision measures. In contrast, the imminent or actual cessation of water supply, i.e., water outage, by such causes as an extreme raw water shortage, major equipment or system failure, sabotage, pollution of the water supply, or electrical power outage call for extreme measures to conserve and make best use of available water.

2. Separate planning and preparedness are devoted to water shortage emergencies and to water outage emergencies. Water conservation measures identified in water shortage emergency planning are applicable first steps which must be instituted in a water outage emergency in order to conserve and make best use of water remaining in the water supply system and in order to obtain time to

initiate other water outage emergency measures identified in this plan.

3. A water outage emergency, characterized by the imminent or actual cessation of water supply may generally be caused by failure of the raw water source through inadequate water quantity or quality, and treatment/distribution system disruption or failure. The result is that the availability of water for human consumption, for fire suppression and for operation of the sanitary sewer system is halted, and emergency measures to furnish water for human consumption and fire fighting and to provide for disposal of human waste are essential.

4. A water shortage emergency is characterized by reduced supply vs. demand through such causes as reduced availability of the raw water source in periods of drought, increased demand by water users in hot, dry weather, partial equipment or system failure which reduces treated water production or delivery through the system, or combinations of these. The result is that demand approaches or exceeds the supply of treated water, and measures for reducing the demand by voluntary or mandatory conservation by water users are necessary. Because of the progressive nature of a water shortage, a shortage is defined by stages that require increasingly stringent conservation measures: Alert Stage: Restriction Stage: and Emergency Stage. A water supply outage is viewed as an extreme Emergency Stage to the final point of having to deal with the cessation of water availability. As the severity of a critical water supply situation diminishes, the severity of water conservation measures required also diminishes. Thus, less restrictive stages are subsequently called during the termination of a water supply emergency.

B. Initiation of Critical Stages

1. Potomac River Water Supply Emergencies

a. Inadequate Raw Water Supply

(1) Criteria specifying the water demand/supply relationship defining initiation of water supply critical stages:

(a) Alert Stage - declared when the total daily withdrawal from the Potomac River is equal to or greater than fifty percent (50%) of the total daily flow,

(b) Restriction Stage - declared when the total daily withdrawal from the Potomac

G-I-9

River is equal to or greater than eighty percent (80%) of the total daily flow.

(c) Emergency Stage - declared when the estimated total daily withdrawal for any day within the ensuing five (5) days from the Potomac River is expected to exceed the daily river flow anticipated.

(d) Water Outage Emergency - declared upon recognition that a condition exists of imminent or actual cessation of water supply.

(2) The Aqueduct will declare the Alert, Restriction, and Emergency Stages; while the local jurisdictions or water supplier whose water supply and/or system is affected by a Water Outage Emergency will declare such an outage emergency. The Alert, Restriction, and Emergency Stages of paragraphs II.B.1.a(1), (b), and (c) are defined by the Potomac River Low Flow Allocation Agreement (dated January 11, 1978) and will be modified in accordance with revisions to this Agreement if they should occur.

(3) Before declaring a stage, the Aqueduct would check with the "U.S. Geological Survey," "Maryland Water Resources Administration" (WRA), and "National Weather Service River District Office" to assure that no immediate change in river flow can be anticipated.

(4) Decision Information Base

(a) Potomac River flow information will be provided by the Army Corps of Engineers, Washington Aqueduct Division. River flow will be measured at the Little Falls gauging station which is maintained by the U.S. Geological Survey. For purposes of gauge measurement interpretation, the U.S. Geological Survey should continue to provide gauge height measurements (through such means as the present, publicly assessable telemark (telephine system) and continually updating rating information which translate river water height to river flow. Potomac River flows provided by the Army

Corps will include metropolitan Washington water withdrawals which occurred during the previous 24-hour period upstream of Little Falls. The National Weather Service will provide, to as accurate a degree as possible, short-range Potomac River flow forecasts (3-day projection) as well as long-range flow forecasts. These flow forecasts plus associated short- and long-range weather forecasts would be used by the Army Corps of Engineers, the Council of Governments and Water Suppliers as a means of anticipating the immediacy of particular emergency stages.

(b) While long- and short-range river flow forecasts are tentative, such forecasts, along with associated weather forecasts, do have value and should be used to indicate the immediacy and possible duration of water shortages. A long-range forecast initiated in the Spring and revised monthly indicating the chance of low flows, would inform local officials and the public of the possibility of water restrictions. A short-range forecast procedure would estimate the potential length of the Alert Stage, Restriction Stage, Emergency Stage, or Water Supply Outage (if caused by a raw water shortage) if low flows did not occur.

(c) The National Weather Service (River District Office Hydrologist) would provide forecasts of both short- and long-range Potomac River flows to the Washington Aqueduct Division and Council of Governments. Short- and long-range weather forecasts would also be provided by the National Weather Service.

The U.S. Geological Survey would also provide supplementary information such as Potomac River Basin ground water levels if requested.

(d) Information delineating Potomac River Water Supply demand is required for initiating particular water supply critical stages.

Each Major Water User would provide withdrawal flows over the preceding 24 hours and a forecast of anticipated short-range changes in demand to the Aqueduct during the Alert Stage, Restriction Stage, Emergency Stage, or Water Supply Outage (if caused by a raw water shortage), or during a generally low flow condition of the Potomac River upon request by the Aqueduct. The Aqueduct would then collect that information daily and use it to determine whether a specific low flow condition exists or can be anticipated.

Water demand forecasts should be used as supplementary information to help indicate the immediacy of a water shortage emergency based on the relationship of water supply demand.

b. Other Water Supply Emergencies

The following potential emergencies other than those due to low Potomac River flows exist and are defined as:

(1) Treatment and/or distribution system disruption or failure due to malfunction of equipment, electrical power failure, etc., may cause a water supply emergency. Local jurisdictions or operating agencies should, according to their detailed implementation plan, declare the emergency and define its extent.

(2) Water quality problems owing to toxic spills, sabotage, etc., may cause a water supply emergency. Public health officials, local jurisdictions or operating agencies should, according to their detailed implementation plan, declare the emergency and define its extent.

2. Non-Potomac River Water Supply Emergencies

a. Inadequate Raw Water Supply

(1) Non-Potomac River Water Supply critical stages are defined and declared by the local governments or water suppliers that are concerned with that portion of the metropolitan Washington area affected.

(2) The affected water supplier will collect, receive, record and accumulate daily reports regarding the available water of the water supply source and the quantities of water being withdrawn from the water source.

(3) The current and projected adequacy of non-Potomac water supplies should be provided by:

(a) Patuxent River-Washington Suburban Sanitary Commission

(b) Occoquan Creek-Fairfax County Water Authority

(c) Goose Creek-City of Fairfax

(d) Broad Run - City of Manassas

(e) Other water suppliers as appropriate.

b. Other Water Supply Emergencies

Potential emergencies other than those due to low Potomac River flows exist and are classified in the same categories as are "Other Water Supply Emergencies" (II.B.1.b.) for the Potomac River; i.e., treatment and/or distribution system disruption or failure, or water quality problems.

C. Termination of Critical States

1. Potomac River Water Supply Emergencies

a. Inadequate Raw Water Supply - criteria specifying the water demand/supply relationship defining termination of water supply critical stages:

(1) The Aqueduct will terminate the Emergency, Restriction, and Alert Stages to the next less critical stage as criteria (II.B.1.2(1), (a), (b) and (c) defining that stage are met (reverse order). This will continue until no critical stage exists.

(2) Water Outage Emergency - The local jurisdiction or water supplier whose water supply and/or system has been affected by a Water Outage Emergency, will anticipate and will determine when causes of the Water Outage Emergency have been overcome, removed, repaired or ameliorated to the extent that the Water Outage Emergency can be terminated.

b. Before terminating a stage, the Aqueduct would check with the "U.S. Geological Survey," "Maryland Water Resources Administration" (WRA), and the "National Weather Service" to assure that no immediate change in river flow can be anticipated.

c. Other Water Supply Emergencies

(1) Water supply emergencies caused by treatment and/or distribution system disruption or failure: Local jurisdictions or operating agencies should, according to their detailed implementation plan, terminate the emergency.

(2) Water supply emergencies caused by water quality problems caused by toxic spills, sabotage, etc.: Putlic health officials, local jurisdictions or operating agencies should, according to their detailed implementation plan, terminate the emergency.

2. Non-Potomac River Water Supply Emergencies

a. Inadequate Raw Water Supply - The local jurisdiction or water supplier whose raw water supply has been affected by water inadequacies will anticipate and will determine when causes of the critical condition have been overcome, removed, repaired, or ameliorated to the extent that the declared water supply critical stage can be terminated.

b. Other Water Supply Emergencies

(1) Water Supply emergencies caused by treatment and/or distribution system disruption or failure: Local jurisdictions or operating agencies should, according to their detailed implementation plan, terminate the emergency.

(2) Water supply emergencies caused by water quality problems caused by toxic spills, sabotages, etc: Public health officials, local jurisdictions or operating agencies should according to their detailed implementation plan, terminate the emergency.

III. WATER SHORTAGE EMERGENCY PROCEDURES

A. General

1. Based on the distinction between water supply shortage and water outage emergency preparedness planning (See *Section II.A), this section addresses notification* and operations procedures to respond to a water shortage. The water conservation measures contained herein are necessary to conserve and make best use of water available to water supply systems and to the extent possible, will *limit the more severe Water Outage Emergency measures* contained in Section IV.

2. Definition of water supply critical stages of a water supply shortage are contained in Section II.B.

3. Water shortage emergencies addressed herein are of two types: Potomac River Raw Water Supply Shortage; and other water supply emergencies.

   a. Potomac River Raw Water Supply Shortages - primarily concern those local jurisdictions and water suppliers dependent upon the Potomac River for water supply. Critical conditions affecting the Potomac River as a raw water source such as inadequate flow or pollution of the water, may cause a raw water shortage affecting consumers throughout the metropolitan Washington area. A response to such regional water shortages is coordinated on a regional basis by the Metropolitan Washington Council of Governments using the "Metropolitan Washington Water Supply Emergency Agreement (WSEA)." Emergency procedures contained herein reflect this regional agreement.

   b. Other Water Supply Emergencies include:

      (1) Potomac River

      Critical conditions affecting Potomac River water supply after it has been withdrawn for treatment and distribution such as system breakdowns, contaminated finished water, etc., which are handled on a local basis with regional assistance if requested (as provided by the WSEA).

      (2) Non-Potomac River

      Critical conditions affecting non-Potomac River water supplies which are independent of the Potomac River for water supply. These critical conditions include raw water inadequacy and pollution of raw water, as well as treatment/distribution system breakdowns, contaminated finished water, etc. These conditions are handled on a local basis with regional assistance if requested (as provided by the WSEA).

4. The emergency operating procedures implemented during a water supply critical stage are the same whether the stage is declared during initiation or termination.

B. Control and Coordination

1. Notification

   a. Potomac River Raw Water Shortage

      (1) Stages of a water shortage (Section II.B.1.a.(1) due to Potomac River low flows are declared by the Washington Aqueduct Division.

      (2) The Aqueduct will inform the coordinator of the Metropolitan Washington Council of Governments as to the water shortage stage (Section II.B.1.a(1) declared plus the flow in the Potomac River and all information used as the basis for declaring the stage.

      (3) As specified in Section II.B.1.a.(3), the River District Office Hydrologist will inform the Aqueduct and the coordinator of long- and short-range weather and Potomac River flow forecasts.

      (4) As specified in Section II.B.1.a.(3), the U.S. Geological Survey will provide hydrologic information to the Aqueduct and the Coordinator upon request.

      (5) The coordinator using the Washington Area Warning Alert System (WAWAS) will:

         (a) Notify the District of Columbia Office of Emergency Preparedness, D.C. Department of Environmental Services, of the water supply critical stage, necessary operations, and other appropriate action (See Annex C, Appendix 1).

(b) Notify the public through local news media using the Local Emergency Broadcasting Procedures (LEBP) if extreme conditions exist. Information provided includes:

1. Water supply critical stage declared
2. Definition of the stage
3. Expected duration of stage
4. Areas affected
5. General type of actions called for now
6. Actions being taken by officials from Local Governments and states, regional, and special purpose agencies in response to this stage after checking with them.
7. General types of actions to be called for in the next stage
8. Request public to anticipate detailed information from Local Government or Water Suppliers as appropriate.

(6) The D.C. Office of Emergency Preparedness using public phone and WAWAS communication will inform the U.S. General Services Administration (GSA), Local Government (Emergency Operating Centers (EOC), and local Water Suppliers of the information provided by the Coordinator, listed in Annex C, Appendix 1. If a local government would like its water distribution management notified separately from the local government EOC notification then the local government should arrange such notification with its water supplier. Local jurisdictions which do not have an EOC and are not responsible for distributing water or enforcing water supply emergency measures should still be notified. Local jurisdictions in such a situation should designate their police or fire department as the contact or make arrangements with the water supplier for notification. Enforcement arrangements should be made with neighboring jurisdictions and the water supplier.

(a) GSA will notify the U.S. Civil Service Commission (CSC) and all affected Federal agencies within GSA's responsibilities of the information in Annex C, Appendix 1. GSA will request CSC to notify Federal agencies within its responsibilities with the same information, and will directly and through CSC

G-I-13

request affected agencies to activate their own water shortage emergency plans and take appropriate action.

(b) Each EOC will notify appropriate government persons of the water shortage. Each Local Government or Water Supplier (as appropriate) affected, will:

1. Notify Local Government agencies required for emergency operations and personnel required to activate the local Emergency Operating Center (EOC).
2. Notify the appropriate State civil defense agency.
3. Notify the Metropolitan Washington Board of Trade and local Chambers of Commerce to request such agencies to notify their member organizations and solicit cooperation in accomplishing emergency measures to be announced.
4. Notify residents of the local jurisdiction by means of the Local Emergency Broadcast Procedures, if necessary.
5. Release information for the public only through designated public information personnel acting in coordination with the public information representative of the Water Supplier (Annex C, Appendix 2).
6. Establish and identify to the public a telephone number or numbers to which individual residents may call for information as to the water shortage and emergency measures placed in effect. The information released through such "Accurate information - Rumor Control" elements established will be limited to information furnished by the local government public information office as coordinated with the public information office of the Water Supplier.

(c) Each Water Supplier or Local Government (as appropriate) affected will:

1. After coordination at the executive level with the local governments concerned, release information to the public by means of the local news media, by means of the AP and UPI Wire Services and directly to news media representatives.

G-I-14

2. Establish and announce to the public a telephone number or numbers to which Major Water Users and those water customers with special cases of believed hardship may call for clarification of conservation procedures. Local Government "Accurate Information" Centers will refer calls received on these matters to the Water Supplier special telephone numbers.
3. All information released to the public will include precautionary statements urging extreme care to prevent fires.
4. Respond to requests for exceptions to announced emergency conservation and restriction measures.

Other Water Supply Emergencies

(1) Definition of Other Water Supply Emergencies is contained in Sections II.B.1.b. and II.B.2.

(2) Initial notification is by Water Suppliers. The Water Supplier whose system is affected will contact (using the WAWAS if available) the following, stating the cause of the emergency, estimated duration, and measures underway to correct the emergency.

(a) Other Water Suppliers in the metropolitan area
(b) Local Governments in the area affected.

(3) Local Governments will declare an emergency if necessary

(4) The affected Local Government(s) or Water Supplier (as appropriate) will continue to notify and communicate with the U.S. General Services Administration, Local Governments, and other Water Suppliers.

Notification procedures are the same as those contained in Section III.B.1.a.(6)(a) - III.B.1.a.(6)(c)

2. Operating Centers

a. Control and coordination of notification and operations will be accomplished to the maximum extent possible through Emergency Operating Centers (EOC) established and activated by Local Governments, Water Suppliers and state civil defense/emergency services agencies to include:

(1) Issuance of emergency notifications.

(2) Supporting the exchange of information and coordination among local executives.

(3) Coordination of public information in:

(a) Providing official information to the news media
(b) Notification to the public through the Local Emergency Boradcast Procedure if the water supply emergency is extreme
(c) Responding to individual resident requests for information if requested to provide such information
(d) Furnishing information to the business community through the Metropolitan Washington Board of Trade and local Chambers of Commerce.

(4) Coordination of preparedness and conduct of fire operations.

(5) Defining, announcing, and supporting health and hygiene measures by the public.

(6) Responding to requests for special assistance from individuals or organizations through the office of an individual designated by the County Executive, or appropriate responsible body.

(7) Generating sources and obtaining support from non-affected jurisdictions, commercial sources, and state and Federal resources to meet the needs of emergency operations.

b. To facilitate coordination among all agencies, Emergency Operating Centers will establish and maintain emergency notification lists and listings of phone numbers and communication means.

G-I-15

(1) Emergency notification lists of key personnel and organizations will include principals and alternates with both office and home phone numbers for each.

(2) Special phone numbers of EOCs not to be released to the public, for direct coordination among EOCs.

(3) WAWAS communications circuits.

(4) Annex B, Appendix 2: Emergency Operating Center Phone Numbers.

(5) Annex B, Appendix 1: Emergency Notification Phone Numbers.

c. Once activated for the emergency, Emergency Operating Centers should plan to operate on a 24-hour per day basis until the emergency is terminated.

C. Implementation and Operations

1. General

a. Once a water supply critical situation occurs, the appropriate stage of emergency declared, and appropriate notification made, specific actions must be implemented to overcome, remove, or ameliorate the situation. In responding to a water shortage, necessary resources must be available for immediate use and conservation measures ready for reducing water demand. Most of this Section, III.C., specifies required water conservation measures necessary to use available water most effectively.

b. Neighboring unaffected local jurisdictions of an area experiencing a water shortage should consider requests for aid such as providing emergency equipment, e.g., portable pumps, temporary piping, and tank trucks. A call for water conservation within the unaffected jurisdiction should only be made if such conservation would provide more water to the affected area.

c. Resources

(1) Local Governments and Water Suppliers will establish and maintain listings of equipment and supplies applicable to the conduct and support of water shortage operations:

(a) Local Government and Water Supplier equipment

(b) Commercially-owned equipment.

(2) Identified equipment available from state and Federal sources.

Attention will be given by Local Governments and Water Suppliers to the acquisition of needed equipment to support water shortage operations through:

(a) "Federal Surplus" and "Excess Property Program" available through civil defense channels.

A local government or vested water supply agency has the authority to institute mandatory restrictions on water use.

2. Water Shortage Alert State (Plan A: Alert)

a. Condition of Water Supply

(1) Potomac River Raw Water Supply Shortage: Alert Stage declared based on indication of potential inadequacy of Potomac River Water, i.e., low flow (See Section II.B.1.a.(1)(a)).

(2) Other Water Supply Emergencies: Indication that a potential shortage of water other than a shortage caused by Potomac River low flows may occur (See Section II.B.1.b. and Section II.B.2)).

b. Operations

(1) For Potomac River Raw Water Supply Shortages, the coordinator of the Metropolitan Washington Water Supply Emergency Agreement will notify Local Governments, Water Suppliers, General Services Administration, and the Public of the Alert Stage and possible forthcoming emergency measures (See Section III.B.1.a.(5). (a) and (b)).

(2) For Other Water Supply Emergencies, the Local Government or Water Supplier, as appropriate, will notify other Local Governments, Water Suppliers, U.S. General Service Administration, and the Public of the Alert condition and possible forthcoming emergency measures (See Section III.B.1.b.(4)).

(a) Check intake structures, raw water pumping stations and other facilities, as appropriate to ensure minimal water losses in operation.

(b) Increase monitoring of finished water demand.

(c) Increase use of weather forecast data and development and use of soil moisture deficit data, including possible employment of weather specialists.

(d) Publicize limitations of physical water system if the limitations affect the water supply situation.

(4) The U.S. General Services Administration, Local Government, and the Metropolitan Washington Board of Trade (and supporting Chambers of Commerce) shall maintain master contact lists and request governmental, commercial, and industrial water users, as appropriate, to:

(a) Check for system leakage by shutting off automatic water make-up on chilled water and heating hot water boiler systems.

(b) Assure that automatic bleed controls are in proper calibration for cooling towers.

(c) Establish daily water meter reading program prior to anyone's entering facility to ascertain leakage.

(d) Maintain correct water levels in cooling towers to prevent overflow on shutdown.

(e) Inspect total plumbing system to assure water-tight conditions of faucets, valves, unions, etc.

3. Water Shortage Restriction Stage (Plan B: Voluntary Compliance)

a. Condition of Water Supply

(1) Potomac River Raw Water Supply Shortage: Restriction Stage declaration based on Potomac River low flow (See Section II.B.1.a(1)(a)).

G-I-16

(2) Other Water Supply Emergencies: Inadequate water or other problem makes demand reduction of up to 15 percent desirable.

b. Operations (Implement all operations of Plan A with the following modifications and additions).

(1) For Potomac River Raw Water Supply Shortages, the coordinator of the Metropolitan Washington Water Supply Emergency Agreement will notify Local Governments, Water Suppliers, and the Public of the Restriction Stage and possible forthcoming emergency measures (See Section III.B.1.a.(5) and (6)).

(2) For Other Water Supply Emergencies, the Local Government or Water Supplier, as appropriate, will notify other Local Governments, Water Suppliers, U.S. General Service Administration, and the Public of the Restriciton condition and possible forthcoming emergency measures (See Section III.B.1.b.(4), and Sections III.B.1.a.(6)(a) - III.B.1.a.(6)(c)).

(3) As a goal, residents should (voluntarily) limit water consumption to 75 gallons per person per day (one bath, one flush per person per day, one laundry per family every other day).

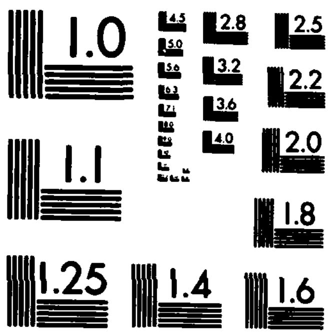
(4) Through the U.S. General Services Administration, Local Government, and the Metropolitan Board of Trade (and supporting Chambers of Commerce) request the following actions be taken by governmental, commercial, and industrial water users as appropriate (Stages I - IIB of Annex F).

(a) Restrict the use of hoses, sprinklers, or other means for sprinkling or watering of shrubbery, trees, lawns, grass, plants, vines, gardens, vegetables, flowers, or any other vegetation. The use of buckets of water for such vegetation is permitted.

(b) Discontinue operation of all water demanding amenities such as ornamental fountains, waterfalls, and reflecting ponds.

AD-A134 159 METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY APPENDIX G NON-STRUCTURAL STUDIES(U) CORPS OF ENGINEERS BALTIMORE MD BALTIMORE DISTRICT SEP 83 MWA-83-P-APP-G 3/5

UNCLASSIFIED F/G 13/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(c) Request general conservation of inside water use, such as:

1. Eating facility dishwashers to be loaded to capacity when used.

2. Food and eating facilities to use minimum amount of water for washing vegetables, fruits and other produce.

3. In tank type toilets, insert plastic bottle filled with gravel or bend the float rod down to reduce fill level by one-fourth.

4. Reduce water pressure to all sinks.

5. Reduce the flow of water on all stop valve urinals and commodes.

6. Eating facility customers to be served water on request only.

(d) All watering hoses to be provided with self closing nozzle valves where outside faucets are equipped with back flow prevention valves.

(e) Restrict the washing of streets, driveways, parking lots, service station aprons, apartments, sidewalks, exterior of homes, office buildings or other outdoor surfaces. The use of buckets of water for such purposes is permitted.

(f) Except for make-up, no swimming or wading pools are to be filled or refilled (e.g., compensation for evaporation and/or spillage).

(g) Washing machines to be loaded to full capacity when used. Businesses such as, but not limited to, Beauty Salons, Barber Shops and Car Washes that wash linens in on-premise washing machines are to load to full capacity and at minimum wash cycle.

(h) The use of water from fire hydrants is prohibited for any purpose other than fire extinguishing or water interconnection, except for essential static or residual fire plan tests.

(i) Restrict the use of water for washing automobiles, trucks, trailers, trailer-houses, or any other type of mobile equipment, except where automatic car washing equipment is employed and a recirculating system is used, which reuses at least 50 percent of the water.

4. Water Shortage Emergency Stage (Plan C-1, C-2, C-3: Mandatory Compliance)

a. Condition of Water Supply

(1) Potomac River Raw Water Supply Shortage: Emergency Stage declaration based on Potomac River low flow (See Section II.B.1.a.(1)(c)).

(2) Other Water Supply Emergencies: Inadequate water or other problem creates a desire for reduced demand of:

(a) 15 - 40 percent under Plan C-1

(b) 40 - 60 percent under Plan C-2

(c) over 60 percent under Plan C-3

b. Plan C-1: Operation (Implement Operations of Plan B with the following modifications and additions)

(1) For Potomac River Raw Water Supply Shortages, the Coordinator of the "Metropolitan Washington Water Supply Emergency Agreement" will notify Local Governments, Water Suppliers, and the Public of the Restriction Stage and possible forthcoming emergency measures (See Section III.B.1.a.(5) and (6)).

(2) For Other Water Supply Emergencies, the Local Government or Water Supplier, as appropriate, will notify other Local Governments, Water Suppliers, U.S. General Services Administration, and the Public of the Restriction condition and possible forthcoming emergency measures (See Section III.B.1.b.(4)).

(3) As a goal, residents should limit water consumption to 75 gallons per person per day. (one bath, one flush per person per day, one laundry per family every other day).

(4) The following restrictions apply to all commercial, industrial, and governmental operations. Water Supply Agency and City/County inspectors with proper identification will be used to enforce restrictions. City/County Police will be used to supplement and/or enforce restrictions as necessary (Stages I - IIC of Annex F).

(a) Governmental, Industrial, Commercial, Retail, and Office Buildings:

Do not cool building interiors until inside temperature reaches or exceeds 25° C (78° F); and shut down system one half hour before closing. Food facilities that require cooling for food storage and preservation are excepted.

(b) Restaurants, Drive-In, Fast Food, and miscellaneous Eating Facilities:

1. Use paper service in lieu of china and glassware.

2. No water to be served except on request.

3. Turn off all water not required for food or drink preparation.

4. Discontinue use of garbage disposal.

5. Reduce floor washing in customer area. Sweep only and damp mop.

(c) Restrooms:

1. Reduce hot and cold water pressure to employee restrooms to amounts only sufficient for sanitary purposes.

2. Stores to close all restrooms except for the minimum number of men's and women's rooms according to public health regulations.

3. Water Shortage - Conservation signs to be installed.

(d) Department and Retail Stores:

1. In addition to Plan B and Plan C-1, Sections (4)(a), (b)&(c) securely turn off all water valves located on exterior of building by closing stop valves located inside building or replacing exterior valve with pipe plug.

2. Disconnect all customer drinking fountains.

(e) Hotels, Motels, Inns and Boarding Houses:

1. Implement Plan B and Plan C-1, Sections (4)(a), (b) & (c).

2. Change bed linen every other day except when there is a change of occupant.

3. Shut off water supply to all public convenience ice cube making machines.

4. Instruct maids to use buckets for bathroom cleaning.

5. Post water conservation signs at each point of water usage in individual rooms as well as public areas.

6. When possible, lower pressure in the water distribution system.

(f) Health Care Facilities including Hospitals, Clinics, Sanitariums, Nursing Homes, Pharmacies, Laboratories, Ambulance Services and Rescue Squads:

1. Implement only those procedures of Plan B and Plan C-1, Sections (4)(a), (b), & (c) which do not inconvenience or endanger intended services.

(g) Dentists and Doctors:

1. Implement Plan B and Plan C-1, Sections (4)(a), (b)&(c).

2. Turn off all continuous water running devices.

(h) Universities and Colleges - Public, Private:

1. Implement Plan B and Plan C-1, Sections (4)(a), (b) & (c) as applicable.

2. Laundry Rooms are to be closed during the hours of 11 a.m. to 7 p.m.

(i) Private Clubs, Public Parks, Golf Courses, Country Clubs and other recreational facilities:

1. Implement Plan B and Plan C-1, Sections (4)(a), (b) & (c).

(j) Landscape and Lawn Watering:

Prohibit the use of hoses, sprinklers, or other means for sprinkling or watering of shrubbery, trees, lawns, grass, plants, *vines, gardens, vegetables, flowers,* or any other vegetation. The use of buckets of water for such vegetation is permitted.

c. Plan C-2: Operations (Implement Operations of Plan C-1 with the following modifications and additions):

(1) As a goal, residents should limit consumption to less than 40 gallons per person per day (one bath, one flush per person per day).

(2) The following restrictions apply to all commercial, industrial, and governmental operations. Water Supply Agency and City/County inspectors with proper identification will be used to enforce restrictions. City/County Police will be used to supplement and/or enforce restrictions as necessary (Stages I - IID of Annex F).

(a) Governmental, Industrial, Commercial, Retail and Office Buildings:

Do not cool building interiors until inside temperature reaches or exceeds 27° C (80° F); plus close all cooling system bleed-off valves. Where multi-units are used, cut off one air conditioner unit. Food facilities that require cooling for food storage and preservation are excepted.

Manufactured products, computer rooms, laboratory and research equipment that are similarly heat-sensitive are excepted.

(b) Restaurants, Drive-In and Fast Food and miscellaneous Eating Facilities:

1. No water to be served to customers except on request.

2. Evaluate for implementing any additional conservation measures.

3. Close ice cream dipper fountans.

4. Discontinue use of ice cubes.

(c) Restrooms:

1. Restrict urinals and toilets to minimal water flow.

(d) Department and Retail Stores:

1. Implement Plan C-1, and Plan C-2, Section (3)(a), (b) & (c).

2. Securely turn off steam boiler used only for alterations. Use steam irons as alternative.

3. Beauty and Barber Shops to do single rinse shampoo only; when doing hair cuts, spray bottles to be used to wet hair instead of sink; disposable paper towels to be used, or linens and towels washed by commercial laundry located in nonimpacted area, when possible.

4. In summer, reduce interior heat loads by turning off as many lighting fixtures as possible.

(e) Hotels, Motels, Inns, and Boarding Houses:

1. Implement Plan C-1, and Plan C-2, Sections (3)(a), (b), (c) & (d).

2. Change bed linens every third day except when there is a change of occupant.

3. All linens and towels to be washed by commercial laundry located in nonimpacted area, when possible.

4. Discontinue use of ice cubes except for food preservation.

(f) Commercial Laundries:

Reduce water consumption by at least 30 percent.

(g) Bottling Plants, restrict operation by:

1. Discontinue refilling returnable bottles.

2. Reduce water consumption by at least 40 percent.

3. Wherever possible, use trucked-in water for all washing and bottling needs.

(h) Landscape and Lawn Watering.

The use of water for outside watering and sprinkling is to be discontinued.

(i) General:

Washing of sidewalks and exterior paved areas, vehicles, building windows and other nonessential items is prohibited.

d. Plan C-3: Operations (Implement Operations of Plan C-2 with the following modifications and additions)

(1) As a goal, residents to limit consumption to less than 30 gallons per day (1 flush per person per day, one bath per person every other day).

(2) Local Governments will request owners of all lakes, wells and other private water supplies to make available these supplies if required during the Emergency.

(3) The following restrictions apply to all commercial, industrial, and governmental operations. Water Supply Agency and City/county Inspectors with proper identification will be used to enforce restrictions. City/County Police will be used to supplement and/or enforce restrictions as necessary (Stages I - III of Annex F).

(a) All nonexcluded Plan C-2 water-cooled air conditioning units to be turned off.

(b) All concrete batching plants are to use only trucked-in water from resources out of the impact area.

(c) All manufacturing plants using water as the base of product shall use only trucked-in water from resources approved by appropriate public health officials out of the impact area.

(4) See "Water Outage Emergency Plan" (Section IV) and take action as appropriate.

IV. WATER OUTAGE EMERGENCY PLAN

A. INTRODUCTION

1. The water outage emergency plan was prepared by the Metropolitan Washington Council of Governments' Disaster and Emergency Preparedness Committee in coordination with the Police Chiefs and Fire Chiefs Committees.

2. The water outage emergency plan addresses that extreme emergency situation in which there is an actual or imminent cessation of water supply. Because of the severity of such a condition, it is considered essential that the plan retain complete identification as an entity so that a reader, to gain

G-I-21

full comprehension of it, will not be required to cross reference while reading it. Therefore, certain definitions, statements of purpose and procedures may be repetitive to other portions of the overall plan.

B. PURPOSE

1. To prescribe the responsibilities and tasks of governmental, regional and special purpose agencies to conserve water, provide emergency water supplies for necessary human consumption and protect the public health, safety and welfare in a water outage emergency affecting all or a portion of the metropolitan Washington area. Specifically, the responsibilities and tasks apply to:

   a. The establishment and operation of emergency water supply points to provide minimum essential water for human consumption to sustain the life and health of residents.

   b. Measures for fire protection and suppression.

   c. Health measures for the sanitary disposal of human waste.

2. To identify the water conservation, health and protective measures to be applied by residents, businesses and private organizations in the area affected by a water outage emergency.

C. DEFINITIONS

1. Water Outage Emergency: A condition in which the supply of water from one or more water suppliers has ceased, or is in jeopardy of cessation or is polluted, and immediate action is required by governments and agencies concerned to provide minimum necessary potable water for human consumption, to inform the public and to protect the health, safety and welfare of the population in the area or areas affected.

2. Water Shortage Emergency: A condition in which the normal supply of potable water from one or more water suppliers is or may be limited to the extent that special water consideration actions or water allocations from available sources are required to protect the health, safety and welfare of the population in the area affected.

D. GENERAL

1. This emergency plan addresses the actions required to respond to a Water Outage Emergency. It recognizes that, although separate planning and preparedness are devoted to Water Shortage Emergencies, water conservation measures identified in water shortage emergency planning are applicable first

steps which must be instituted in a water outage emergency in order to conserve and make best use of water remaining in the water supply system and in order to obtain time to initiate other water outage emergency measures identified in this plan.

2. A water outage emergency is characterized by the imminent or actual cessation of water supply by such causes as failure of the raw water source, equipment or system failure, sabotage, pollution of the water supply, or electrical power outages affecting the system. The result is that the availability of water for human consumption, for fire suppression and for operation of the sanitary sewer system is halted, and emergency measures to furnish water for human consumption and fire fighting and to provide for disposal of human waste are essential.

3. A water shortage emergency is characterized by reduced supply vs. demand through such causes as reduced flow of the raw water source (e.g., Potomac River) in period of drought, increased demand by water users in hot, dry weather, partial equipment or system failure which reduces treated water production or delivery through the system, or combinations of these. The result is that demand approaches or exceeds the supply of treated water, and measures for equitably reducing the demand by voluntary or mandatory conservation by water users are necessary.

E. EMERGENCY PROCEDURES

1. Emergency Notification of Water Outage Condition:

   Upon determination that a Water Outage Emergency is imminent or exists, whether by extension of a Water Shortage Emergency or by reason of an occurrence leading directly to a Water Outage Emergency, the following emergency notifications will be accomplished by the agencies indicated (Appendix 1, Annex B: Emergency Notification List):

   a. The Water Suppliers whose systems are affected will immediately notify the following, stating the cause of the outage, the expected time to a "no-water" condition, estimated duration of the outage, if available, and measures underway to correct the outage.

      (1) Other Water Suppliers/Distributors in the affected area.

      (2) Local Governments in the area affected.

(3) U.S. General Services Administration.

(4) The news media by means of the AP & UPI wire services.

b. Each Local Government affected will notify:

(1) The executive and other key officials appropriate to be informed.

(2) Local government agencies required for emergency operations and personnel required to activate the local Emergency Operating Center (EOC).

(3) The appropriate State civil defense agency.

(4) The Washington Board of Trade and major local Chambers of Commerce to request such agencies to notify their member organizations and solicit cooperation in accomplishing emergency measures to be announced.

(5) The residents of the local jurisdiction by means of the Local Emergency Broadcast Procedure (first notification) to provide official emergency information and instructions necessary for public response to the emergency conditions and support of emergency measures to be instituted.

c. The U.S. General Services Administration (GSA) will notify the U.S. Civil Service Commission (CSC) and all affected Federal agencies within GSA's responsibilities. GSA will also request CSC to notify Federal agencies within its responsibilities.

2. Emergency Public Information

After Emergency Notifications are accomplished, the public will be kept informed and will be advised of conservation measures, measures for public health, and safety measures for prevention and suppression of fires, as follows:

a. The Water Supplier or Water Distributor, after coordination at the executive level with local governments concerned, will release information to the public by means of the news media, by means of the AP & UPI wire services and directly to news media representatives.

b. The local governments will release information for the public only through designated public information personnel acting in coordination with the public information representatives of the Water Supplier.

G-I-22

c. The local governments concerned will establish and identify to the public a telephone number or numbers to which individual residents may call for information as to the Emergency Water Outage and emergency measures placed in effect. The information released through such "Accurate Information-Rumor Control" elements established will be limited to information furnished by the local government public information office as coordinated with the public information office of the Water Supplier.

d. The Water Supplier or Water Distributor will establish and announce to the public a telephone number or numbers to which Major Water Users and those water customers with special cases of believed hardship may call for clarification of conservation procedures and requests for exception believed justified. Local government "Accurate Information" centers will refer calls received on these matters to the Water Supplier special telephone numbers.

e. All information released to the public will include precautionary statements urging extreme care to prevent fires and explanatory statements of hygienic measures to care for human waste when nonpotable water is not available for flushing toilets.

3. Emergency Operations:

Emergency operations will be initiated at the direction of Executives of the local governments affected and the Executive of the Water Supplier.

a. Based upon emergency powers provided by law, an Emergency Proclamation will be issued and publicized to give force and effect to required emergency measures.

b. If not already ordered into effect, the most stringent water conservation measures contained in approved Water Shortage Emergency plans will be ordered enforced.

(1) The Water Supplier will notify major water users of the requirement and will maintain a record of those so notified.

(2) The local governments concerned will support the inspection and enforcement effort by furnishing qualified personnel to operate under the control of inspectors of the Water Supplier. This may require close coordination and joint agreement between local governments and their water suppliers/distributors.

(3) Local governments will furnish necessary police support to enforcement efforts when requested by the Water Supplier.

c. The Water Supplier will notify other Water Suppliers and jurisdictions not affected directly by the water emergency of the need to institute water conservation measures when such would contribute to the general conservation of the area water supply and permit transfer of water from other suppliers into the system affected by the water outage.

d. The Water Supplier, in coordination with the local governments, will arrange for transfer of water from other Water Suppliers to the system affected by means of existing interconnects or by expedient interconnects using available pumping units, such as fire pumpers. All interconnecting pipes will be adequately disinfected.

(1) Local governments will furnish such pumpers as a matter of priority when requested.

(2) Local government fire departments will arrange for needed replacement and augmentation pumper support on preparation for possible fire operations by requesting necessary units from adjacent jurisdictions under the provision of existing mutual aid agreements.

e. The Local Governments and the Water Supplier, in coordination, will establish Emergency Water Supply Points (EWSP) within the area of the water outage to provide minimum essential supplies of potable water to residents for human consumption at a rate of ½ gallon of water per person per day. This water would be provided by unaffected jurisdictions (within and outside the Washington area), which would coordinate their efforts with State and civil defense authorities. Tank trucks and, if necessary, fire department pumpers would be used to transport the water in most cases. All water from Emergency Water Supply Points will be adequately disinfected.

(1) Priority for location of EWSP will be given to facilities evenly distributed through the area and under local government control, such as public schools, fire stations and police stations.

(2) As EWSP equipment becomes available, second priority will be given to other EWSP locations so as to gain improved distribution using such locations as church parking lots, shopping centers and apartment building parking lots as can be arranged with facility owners and supported by available equipment.

(3) Equipment and personnel to establish EWSP will be used in the following order:

(a) Local Government and Water Supplier resources.

(b) Resources from adjacent, nonaffected jurisdictions and Water Suppliers.

(c) Commercial resources (e.g., water transport companies, milk producers).

(d) State resources, including National Guard when authorized by the Governor.

(e) Federal resources, including military forces when authorized by appropriate authority.

(4) The Water Supplier will establish water purification points on available water sources (e.g., lakes, quarries) or will arrange with nonaffected Water Suppliers for the establishment of resupply points, for refilling water transport vehicles used to provide potable water to Emergency Water Supply Points. All equipment used will be sterilized.

(5) Local governments will provide necessary police support for traffic and crowd control at EWSP and for guiding those water transport vehicles which are furnished by other jurisdictions to assigned EWSP locations and refill points.

(6) Each local government will publicize the location of Emergency Water Supply Points in accordance with the provisions of Section E.2., above.

f. Local Governments affected will prepare for and conduct fire suppression operations utilizing the *following:*

(1) Available "tank wagons."

(2) Tank wagons obtained under mutual aid agreements with nonaffected jurisdictions.

(3) When needed, water transport vehicles from Emergency Water Supply Points.

(4) Fire department water resupply point locations identified in advance and established by local fire departments at streams, ponds or other water sources.

(5) When needed, water resupply points established to refill transport vehicles from Emergency Water Supply Points.

g. Local Governments affected will prescribe hygienic measures for human waste disposal in recognition that water outage precludes flushing of toilets. They will use local health and environmental agencies to determine specific measures for the particular situation including the following:

(1) Prescribing sources of water for collection (rainwater or streams and ponds not safe for human consumption) which can be used for periodic toilet flushing.

(2) Use of expedient toilets made with trash or garbage cans or similar containers partially filled with ½ measuring cup of household laundry bleach per gallon of water sufficient to cover waste material.

(3) Use of outside "slit" trenches with available lime to cover waste material.

(4) Location of commercial chemical toilets at public locations such as near Emergency Water Supply Points.

(5) Publicizing necessary measures as provided in Section E.2., above.

h. Local Governments will request hospitals and nursing homes to employ emergency water supplies and emergency generating equipment, if required, maintained in accordance with federal regulations.

i. Local Governmens will supply minimum necessary potable water to detention facilities.

j. Local Governments will request owners of private water systems and wells to restrict the use of water, so as to make such supplies of water available to meet human needs should the emergency dictate, to protect the water table and to make water available for fire suppression as needed.

k. Local Governments will request assistance of suitable organizations, such as the American Red Cross, Salvation Army and Meals-on-Wheels, to deliver minimum essential supplies of potable water to the aged and infirm. unable otherwise to obtain such supplies.

l. Should the water outage emergency be of such severity and expected duration, local governments, in conjunction with the Water Suppliers, will consider recommending to the public that individuals and family members whose immediate presence in the area is not essential be relocated to available accommodations outside the emergency area.

F. TERMINATION OF A WATER OUTAGE EMERGENCY

1. The Water Supplier, whose system has been affected by a Water Outage Emergency, will anticipate and will determine when causes of the Water Outage Emergency (cf. paragraph D.2., above) have been overcome, removed, repaired or ameliorated to the extent that the Water Outage Emergency can be terminated. The Water Supplier, in coordination with the Coordinator designated in the Water Supply Emergency Agreement, will determine whether water supply conditions existing at termination of the Water Outage Emergency necessitate and justify recommendation that a Stage of Water Supply shortage be instituted.

2. The Water Supplier concerned (paragraph F.1., above) will notify those agencies identified in paragraphs E.1.a(1)-(3), above, of:

a. Effective time and date of Termination of the Water Outage Emergency.

b. Recommended Water Shortage Emergency stage, if any, determined as indicated in paragraph F.1., above.

3. If the Water Outage Emergency is terminated with no succeeding Water Shortage stage recommended, notification to the public will be made by the Water Supplier and the local governments concerned in accordance with paragraphs E.2.a and b, above.

4. If the Water Outage Emergency is terminated, but with reversion to a particular water shortage stage (cf paragraph F.1., above), notifications will be initiated by the Coordinator designated *in the Water Supply Emergency* Agreement in accordance with that plan. Such notifications will include information that the water outage emergency has been terminated in addition to the specific water shortage stage to be implemented.

G. CONTROL AND COORDINATION

1. Control and coordination of operations will be accomplished to the maximum extent possible through Emergency Operating Centers established and activated by Local Governments, Water Suppliers, and State civil defense/ emergency services agencies to include:

a. Issuance of emergency notifications.

b. Supporting the exchange of information and coordination among Executives.

c. Coodination of public information in:

(1) Providing official information to the news media.

(2) Initial notification to the public through the Local Emergency Broadcast Procedure.

(3) Responding to individual resident requests for information.

(4) Furnishing information to the business community through the Board of Trade and Chambers of Commerce.

d. Coordination of preparedness and conduct of fire operations.

e. Defining, announcing and supporting health and hygiene measures by the public.

f. Responding to requests for exceptions to announced emergency conservation and restrictive measures.

g. Responding to requests for special assistance from individuals or organizations.

h. Generating sources of water and obtaining support from nonaffected jurisdictions, commercial sources, and State and federal resources to meet the needs of emergency operations.

i. Issuance of notification of termination of water outage emergency and subsequent water shortage stages as may be determined necessary.

2. To facilitate coordination among all agencies, Emergency Operating Centers will establish and maintain emergency notification lists and listings of phone numbers and communication means:

a. Emergency notification/lists of key personnel and organizations will include principals and alternates with both office and home phone numbers for each.

b. Special phone numbers at EOCs not to be released to the public, for direct coordination among EOCs.

c. WAWAS communications circuits.

d. Appendix 2, Annex B: Special Emergency Operating Center Phone Numbers.

3. Once activated for the emergency, Emergency Operating Centers should plan to operate on a 24-hour per day basis until the emergency is terminated.

H. RESOURCES

1. Local Governments and Water Suppliers will establish and maintain listings of equipment and supplies applicable to the conduct and support of Water Outage Emergency Operations:

a. Local Government and Water Supplier equipment.

b. Commercially-owned equipment.

c. Identified equipment available from State and Federal sources.

2. Attention will be given by Local Governments and Water Suppliers to the acquisition of needed equipment to support Water Outage Emergency operations through:

a. Federal Surplus and Excess Property Program available through civil defense channels.

3. Prepared listings of available equipment will be coordinated and exchanged among Emergency Operating Centers.

I. PUBLIC EDUCATION

1. Although not specifically a part of this plan, but essential to its successful implementation in time of Water Outage Emergency, is the education of the public to prepare for and understand the emergency measures required.

2. Upon approval of this plan, Local Governments and Water Suppliers will initiate and continue a public education campaign to convince the public in their area of responsibility that:

a. Water Supply Emergencies are possible.

b. It is to the best interest of individuals, families and private organizations to prepare for such emergencies and to obtain in advance and maintain emergency supplies to assist themselves, including an emergency water supply for human consumption of ½ gallon per individual per day for fourteen (14) days.

c. Utmost care during water emergencies to prevent fires is essential.

d. Plans and supplies for individual, family and organizational emergency hygienic measures are needed to protect health and well-being.

3. Local Governments and Water Suppliers will coordinate public education campaigns.

G-I-26

METROPOLITAN WASHINGTON WATER SUPPLY EMERGENCY PLAN

ANNEXES

A. PARTICIPATING AGENCIES

B. EMERGENCY NOTIFICATION CONTACTS

APPENDIX 1: EMERGENCY NOTIFICATION LIST
APPENDIX 2: SPECIAL EMERGENCY OPERATING CENTER PHONE NUMBERS

C. ESSENTIAL INFORMATION FOR DISSEMINATION

APPENDIX 1: EMERGENCY OPERATING CENTER INFORMATION
APPENDIX 2: PUBLIC/MEDIA INFORMATION

D. WATER SUPPLY EMERGENCY ORDINANCE(S)

E. WATER SUPPLY SERVICE AREAS AND PRESSURE ZONES: METROPOLITAN WASHINGTON

F. FAIRFAX COUNTY: PROPOSED RESTRICTIONS ON WATER USE

INFORMATION SHOULD BE REVIEWED FOR ACCURACY AT LEAST SEMI-ANNUALLY.

G-I-27

WATER SUPPLY EMERGENCY PLAN

ANNEX A

PARTICIPATING AGENCIES

The following list of Participating Agencies within Annex A are anticipated to adopt and participate in this Plan. While some agencies are more directly affected than others, all are affected in some degree.

ANNEX A: PARTICIPATING AGENCIES
(cf. Section I.A.1.)

I. Local Governments

A. City of Alexandria
B. Arlington County
C. City of Bowie
D. City of College Park
E. District of Columbia
F. Fairfax City
G. Fairfax County
H. City of Falls Church
I. City of Gaithersburg
J. City of Greenbelt
K. Loudoun County
L. Montgomery County
M. Prince George's County
N. Prince William County
O. City of Rockville
P. City of Takoma Park
Q. City of Manassas
R. Town of Poolesville

II. Regional Organizations

Metropolitan Washington Council of Governments (COG)

III. State Governments

A. District of Columbia

B. Maryland:

1. Civil Defense & Disaster Preparedness Agency
2. Water Resources Administration

C. Virginia

1. Office of Emergency Services
2. Water Control Board

IV. Federal Government:

A. Defense Civil Preparedness Agency, Region II
B. General Services Administration
C. Department of Agriculture, including National Agricultural Research Center (Beltsville)

D. Department of Commerce, including National Bureau of Standards
E. Department of Defense, including Army Coprs of Engineers, Washington Aqueduct Division

F. Department of Energy, including (formerly) AEC
G. Department of Health, Education and Welfare, including National Institutes of Health and St. Elizabeth's Hospital
H. Department of the Interior: National Park Service
I. Department of Transportation: Fairbanks Highway Research Station
J. Department of the Treasury: Bureau of Printing and Engraving
K. The Architect of the Capitol
L. Government Printing Office
M. National Aeronautics and Space Administration
N. U.S. Postal Service
O. Smithsonian Institution
P. Veteran's Administration: Washington V.A. Hospital

V. <u>Water Suppliers</u>:

A. Washington Aqueduct Division, Baltimore District, U.S. Army Corps of Engineers
B. Washington Suburban Sanitary Commission
C. Fairfax County Water Authority
D. Arlington County, Virginia
E. City of Bowie, Maryland
F. City of Falls Church, Virginia
G. City of Fairfax, Virginia
H. City of Rockville, Maryland
I. Virginia American Water Company (Alexandria and portions of Prince William County)
J. City of Manassas
K. Town of Poolesville

G-I-29

METROPOLITAN WASHINGTON WATER SUPPLY EMERGENCY PLAN

ANNEX B: EMERGENCY NOTIFICATION CONTACTS

This annex consists of two appendices.

Appendix 1 is the emergency notification list. It provides telephone numbers and ACC call signs to be used by water suppliers, local governments, the U.S. General Services Administration and State civil defense agencies in completing emergency notification procedures.

Appendix 2 is a listing of special emergency operating center telephone numbers that are not listed or released to the public. Use of these numbers will facilitate coordination among the EOC's during periods when other telephone lines may be inundated with calls.

APPENDICES: 1 - EMERGENCY NOTIFICATION LIST

2 - SPECIAL EMERGENCY OPERATING CENTER PHONE NUMBERS

LOCAL WATER SUPPLY EMERGENCY PLAN — As of Jan. 1979

ANNEX B: EMERGENCY NOTIFICATION CONTACTS

APPENDIX 1: EMERGENCY NOTIFICATION PHONE NUMBERS

I. To Be Notified by the Water Supplier:

A. Local Governments

Local Governments	Telephone	ACC Call Sign
1. City of Alexandria	(703) 548-6000	Alexandria CD
2. Arlington County	(703) 558-2222	Arlington County Police
3. City of Bowie	(Prince George's County EOC will notify)	
4. City of College Park	(Prince George's County EOC will notify)	
5. District of Columbia	(202) 727-6161	D.C. Office of Emergency Preparedness
6. Fairfax City	(703) 591-5511	Fairfax City Police & Fire
7. Fairfax County	(703) 691-2233	Fairfax County EOC
8. City of Falls Church	(703) 241-5050	Falls Church Police
9. City of Gaithersburg	(Montgomery County EOC will notify)	
10. City of Greenbelt	(Prince George's County EOC will notify)	
11. Loudoun County	(703) 777-2243	Loudoun CD
12. Montgomery County	(301) 279-1251	Montgomery County CD
13. Prince George's County	(301) 779-1150	Prince George's OEP
14. Prince William County	(703) 368-1090	Prince William CD
15. City of Rockville	(Montgomery County EOC will notify)	
16. City of Takoma Park	(Montgomery County EOC will notify)	
17. City of Manassas	(703) 361-4121	Manassas Police
18. Town of Vienna	N/A	
19. Town of Poolesville	(Montgomery County EOC will notify)	

B. Water Suppliers/Distributors

1. Washington Aqueduct Div., Baltimore Division USA Corps of Engineers	(202) 282-2753 (202) 282-2700	(7:30 a.m.-4:00 p.m.) (4:00 p.m.-7:30 a.m.)
2. District of Columbia (DES)	(202) 767-7651 (202) 462-3420	(7:30 a.m.-4:30 p.m.) (4:00 p.m.-7:30 p.m.)
3. Washington Suburban Sanitary Commission	(202) 699-4555	N/A
4. Fairfax County Water Authority	(703) 698-5800	N/A
5. Arlington County	(703) 558-2230 (703) 558-2248	(8:00 a.m.-5:00 p.m.) (5:00 p.m.-8:00 a.m.)
6. City of Bowie	(301) 262-8877	N/A
7. City of Fairfax	(703) 385-7920 (703) 591-5511	(8:30 a.m.-5:00 p.m.) (5:00 p.m.-8:30 a.m.)
8. City of Falls Church	(703) 241-5044	N/A
9. City of Rockville	(301) 424-8000	N/A
10. Virginia American Water Co. (Alexandria & Dale City)	(703) 549-0909/7080 (703) 780-5229 (T. Jones, Jr.) or (703) 590-4363 (R. Eiben)	N/A Off-Duty/Night
11. City of Manassas	(703) 361-4104 x 46 (703) 361-4121	(8:30 a.m.-5:00 p.m.) (5:00 p.m.-8:30 a.m.)
12. Town of Vienna	(703) 938-8000	
13. Town of Poolesville	(301) 428-8927 (301) 349-5411	(8:30 a.m.-5:00 p.m.) (5:00 p.m.-8:30 a.m.)

G-I-29

C. U.S. General Services Administration (GSA):

1. FPA Communications Center	(202) 755-8783 (202) 472-1111	

D. Wire Services:

1. Associated Press (AP)	(202) 833-5368	
2. United Press Intnl. (UPI)	(202) 637-3747	

II. To be Notified by Local Governments:

In accordance with Local Government standing procedures and established emergency notification lists:

A. Executive

B. Key Officials

C. Operating Agencies

D. Predesignated representatives of operating agencies to report to the Emergency Operating Center for the control and coordination of emergency operations.

E. The appropriate State civil defense agency:

	Telephone	ACC Call Sign
1. Maryland Civil Defense and Disaster Preparedness Agency	(301) 486-4422	Maryland CD
2. Virginia Office of Emergency and Energy Services	(804) 272-1441	Virginia CD
F. Metropolitan Washington Council of Governments	(202) 223-6800 Ext. 342	N/A
G. Washington Board of Trade	(202) 857-5900	
H. Local Chamber of Commerce	(Varies with each locality)	
I. Local residents per Metropolitan Washington Local Emergency Broadcast Procedure	(As appropriate)	

III. To be Notified by GSA:

A. Federal agencies occupying facilities within local jurisdictions affected by the Water Supply Emergency.

B. GSA facilities within those jurisdictions.

C. Civil Service Commission.

IV. To be Notified by Appropriate State Civil Defense Agencies:

A.	Water Control Board by Virginia	(703) 750-9111	N/A
B.	Virginia Health Department		
	Eric Bartsch	(804) 786-1760	N/A
	John Capito	(703) 825-6772	N/A
C.	Water Resources Administration by Maryland	(301) 269-3846 -3675	N/A

G-I-30

As of January 1979

LOCAL WATER SUPPLY EMERGENCY PLAN
ANNEX B: EMERGENCY NOTIFICATION CONTACTS
APPENDIX 2: SPECIAL EMERGENCY OPERATING CENTER PHONE NUMBERS*

Telephone numbers, not listed or released to public, for direct coordination among EOC's (Cf. Sections III.B.2.6. and IV.G.2.b.).

		Telephone	ACC Call Sign
I.	Local Government EOC's		
A.	City of Alexandria	(703) 750-6522/6526	Alexandria CD
B.	Arlington County	(703) 558-2222	Arlington County Police
C.	District of Columbia	(202) 727-6700 (rotary)	D.C. Office of Emergency Preparedness
D.	Fairfax County	(703) 691-2243	Fairfax EOC
E.	City of Falls Church	(703) 241-5050	Falls Church Police
F.	Loudoun County	(703) 777-2243	Loudoun CD
G.	Montgomery County	(301) 424-4734 (Rotary)	Montgomery County CD
H.	Prince George's County	(301) 864-5246	Prince George's OEP
I.	Prince William County	(703) 368-0800	Prince William CD
J.	City of Manassas	(703) 361-4121	Manassas Police
K.	Town of Vienna	N/A	
II.	Water Supplier Operating Centers:		
A.	Washington Aqueduct Division Baltimore District USA Corps of Engineers	(202) 282-2753 (202) 282-2700	(7:30 a.m.-4:00 p.m.) (4:00 p.m.-7:30 a.m.)
B.	District of Columbia (DES)	(202) 767-7651 (202) 462-3420	(7:30 a.m.-4:00 p.m.) (4:00 p.m.-7:30 a.m.)
C.	Washington Suburban Sanitary Commission	(202) 699-4555	N/A
D.	Fairfax County Water Authority	(703) 698-5800	N/A
E.	City of Bowie	(Notification through Prince George's CD)	
F.	City of Fairfax	(703) 385-7920	
G.	City of Falls Church	(703) 241-5044	
H.	City of Rockville	(Notification through Montgomery County EOC)	

I.	Virginia American Water Company	(703) 549-7080/0909	N/A
	or	(703) 780-5229 (T. Jones, Jr.) (703) 590-4363 (R. Eiben)	Off Duty/Night
J.	City of Manassas	(703) 361-4104 (703) 361-4121	(8:00 a.m.-4:30 p.m.) (4:30 p.m.-8:00 a.m.)
K.	Arlington County	(703) 558-2230 (703) 558-2248	(8:00 a.m.-5:00 p.m.) (5:00 p.m.-8:00 a.m.
L.	Town of Poolesville	(Notification through Montgomery County EOC)	

NOTE: NOT ALL JURISDICTIONS HAVE "NON-RELEASABLE" NUMBERS.

G-I.31

METROPOLITAN WASHINGTON WATER SUPPLY EMERGENCY PLAN

ANNEX C

This annex consists of two appendices.

Appendix 1 lists a set of emergency information items to be communicated by the District of Columbia Emergency Operating Center to affected Emergency Operating Centers during a water supply emergency.

Appendix 2 lists sets of emergency information items to be communicated by Public Information Offices of affected Local Government Agencies (Annex A) to the news media and public.

APPENDICES: 1 - EMERGENCY OPERATING CENTER INFORMATION

2 - PUBLIC/MEDIA INFORMATION DISSEMINATION BY PUBLIC INFORMATION OFFICES

G-I-32

METROPOLITAN WASHINGTON WATER SUPPLY EMERGENCY PLAN

ANNEX C: ESSENTIAL INFORMATION FOR DISSEMINATION
(cf. Section III.B.1.a.(5)&(6))

APPENDIX 1: <u>EMERGENCY OPERATING CENTER INFORMATION</u>

I. Nature of emergency (shortage or outage).

II. Jurisdiction(s) affected and how.

III. Level of water demand reduction to be implemented: specified by water supply critical stage.

IV. Duration of emergency, if predictable.

V. Notification of key officials in accordance with existing emergency notification plans. (If necessary, notification of need to make any legally required public notice of mandatory action.)

METROPOLITAN WASHINGTON WATER SUPPLY EMERGENCY PLAN

ANNEX C: ESSENTIAL INFORMATION FOR DISSEMINATION
(cf. Section III.B.1.a.(6)(b)5)

APPENDIX 2: <u>PUBLIC/MEDIA INFORMATION DISSEMINATION BY PUBLIC INFORMATION OFFICES</u>

I. <u>Alert Stage</u>

Information to be released to the news media and the public will include the following:

A. Cause of the alert and definition of Alert stage
B. Expected duration
C. Areas affected
D. Appropriate contact persons and telephone numbers at the water supply agency and/or local government for the media and/or the public to contact for additional information.
E. When the next announcement can be expected
F. Actions required in next stage

II. <u>Restriction Stage</u>

Information to be released to the news media and the public will include the following:

A. Why voluntary conservation is being requested
B. Definition of Restriction stage
C. Expected duration
D. Areas affected
E. Voluntary conservation actions the public is asked to take as specified in the Metropolitan Washington Water Supply Emergency Agreement
F. Appropriate contact persons and telephone numbers at the water supply agency and/or local government for the media and/or public to contact for additional information
G. When the next announcement can be expected
H. Actions required in next stage

III. <u>Emergency Stage</u>

Information to be released to the news media and the public will include the following:

A. Why emergency restrictions are in effect
B. Definition of Emergency stage
C. Expected duration
D. Areas affected
E. Mandatory conservation actions the public is required to take as specified in the Metropolitan Washington Water

Supply Emergency Agreement

F. Enforcement and Penalties

G. Appropriate contact persons and telephone numbers at the water supply agency and/or local government for the media and/or public to contact for additional information

H. When the next announcement can be expected.

IV. Water Outage Emergency

(see Emergency Stage above.)

V. Termination

As the severity of a water supply emergency diminishes, allowing the termination of particular critical stages, information to be released to the news media and the public will iterate the information items listed above (I-IV) for specified stages plus indicating:

A. The stage terminated

B. The criteria met for termination of the stage (may be different for initiating the stage).

If a critical stage is terminated with no succeeding stage declared information will be disseminated:

1) indicating that critical water supply conditions have ended; and

2) the prospect of future critical conditions.

METROPOLITAN WASHINGTON WATER SUPPLY EMERGENCY PLAN

ANNEX D

WATER SUPPLY EMERGENCY ORDINANCE (S)
(to be inserted by user)

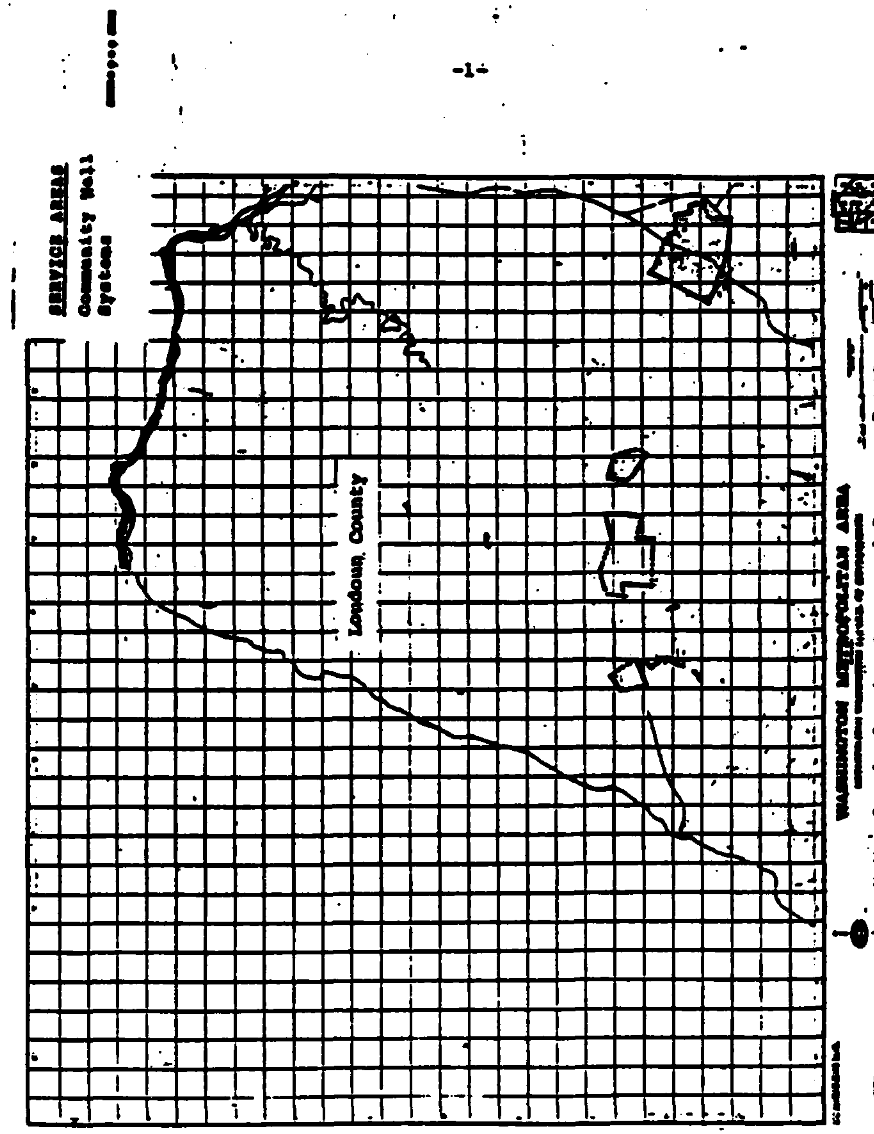
This annex contains the local water supply emergency ordinance(s) of the jurisdiction for which the user of this plan is responsible during a water supply emergency.

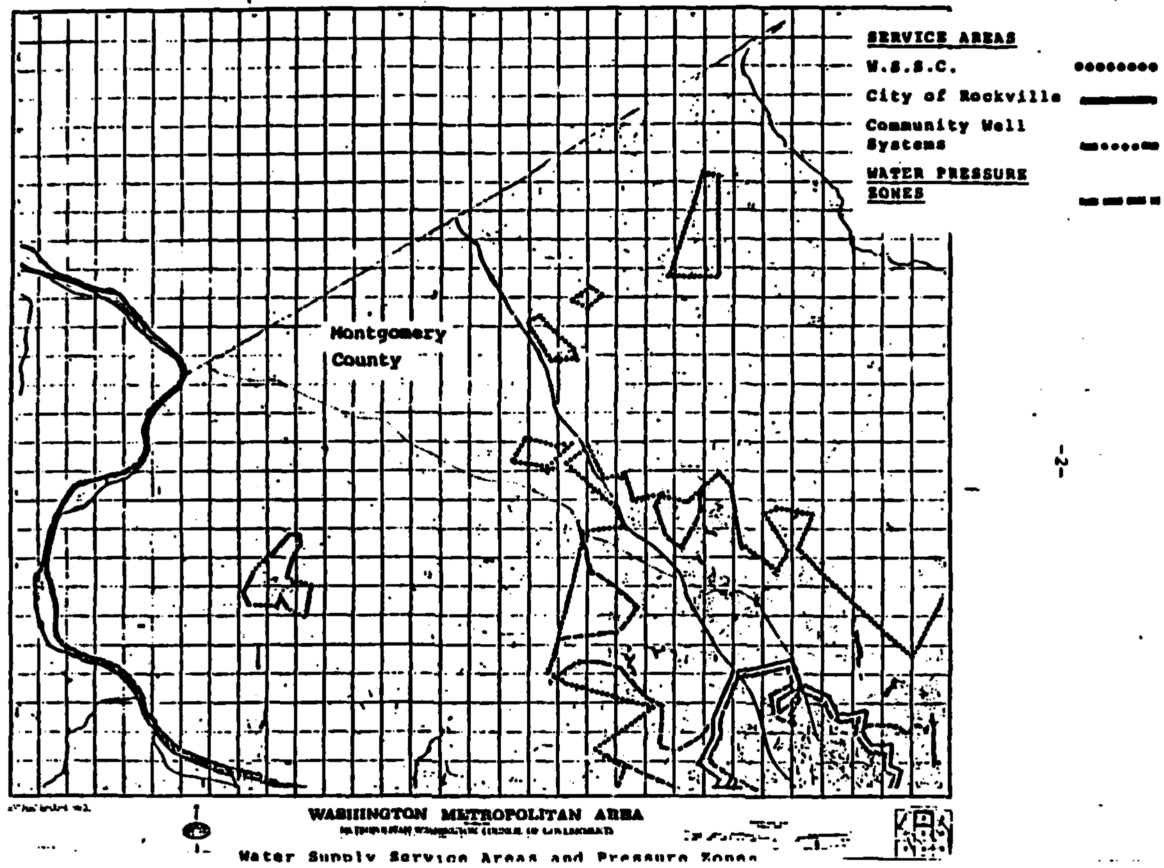
METROPOLITAN WASHINGTON WATER SUPPLY EMERGENCY PLAN

ANNEX E

WATER SUPPLY SERVICE AREAS AND PRESSURE ZONES:
METROPOLITAN WASHINGTON

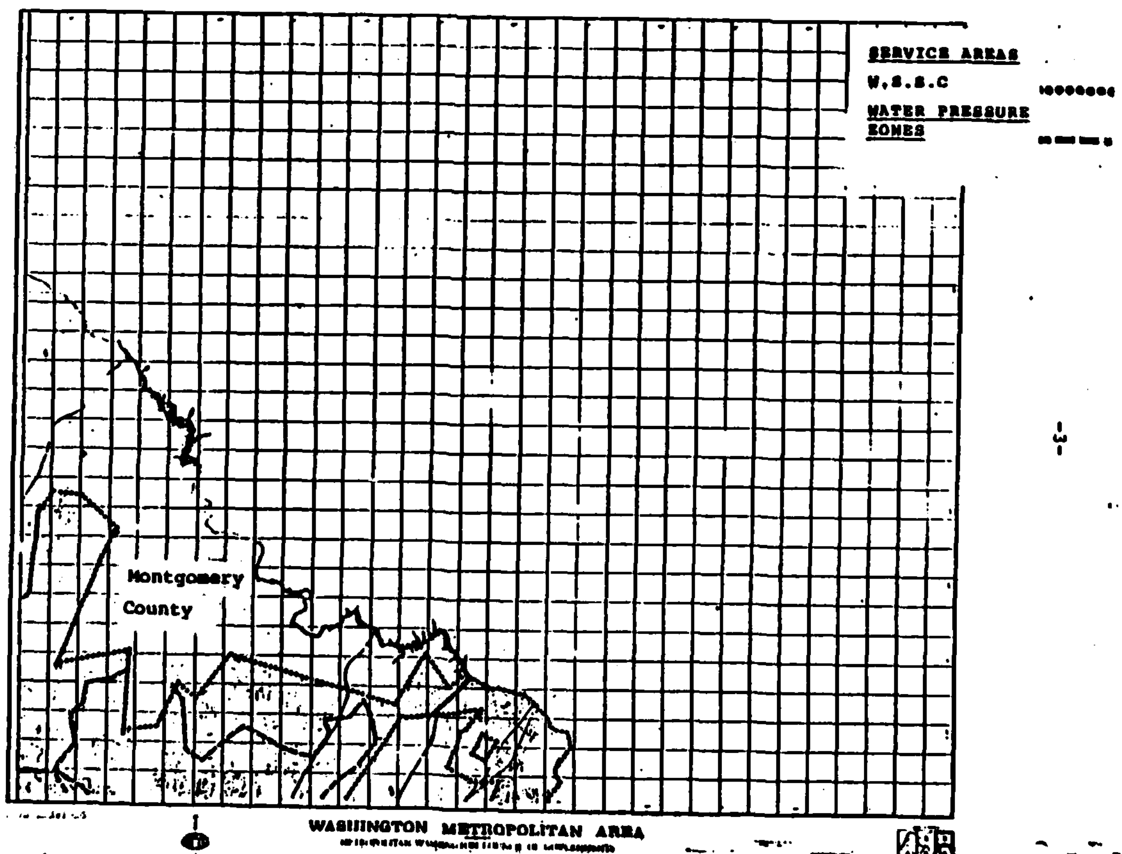
The following maps of water service areas and pressure zones provides an overview of water distribution in the metropolitan Washington area.





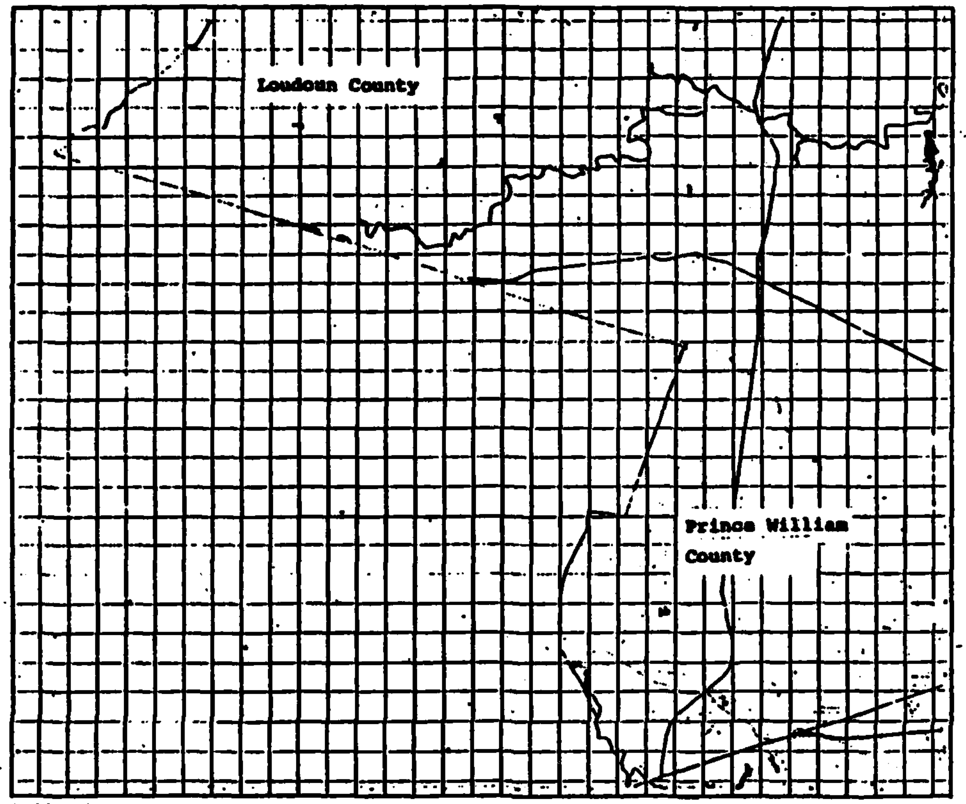
Water Supply Service Areas and Pressure Zones

-2-



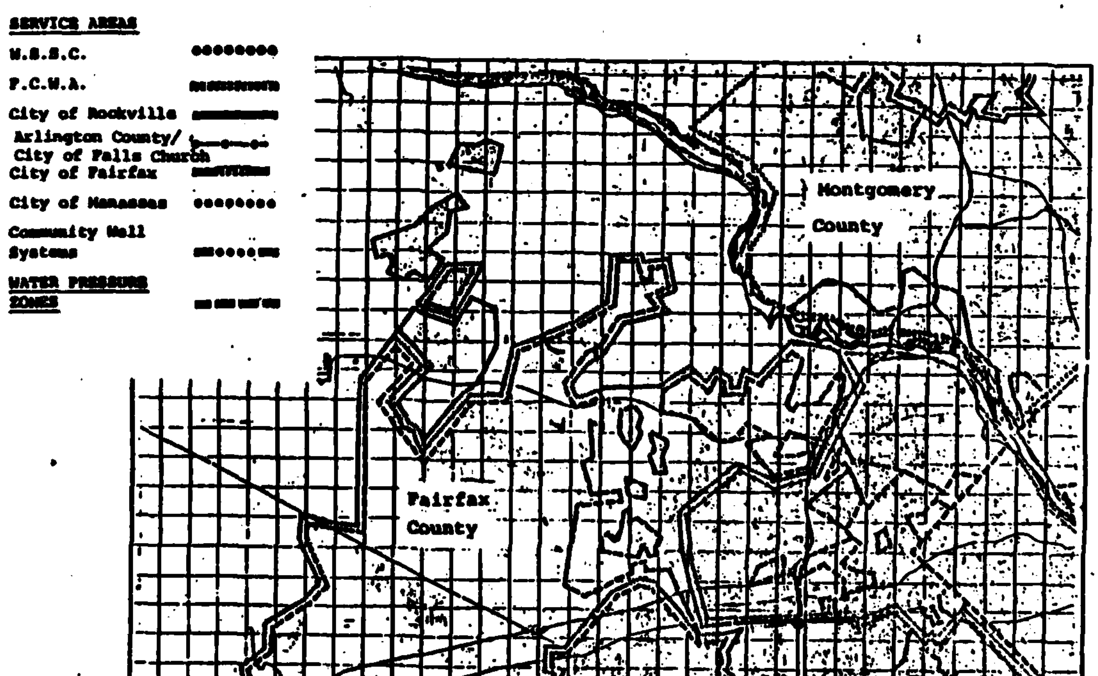
Water Supply Service Areas and Pressure Zones

-3-



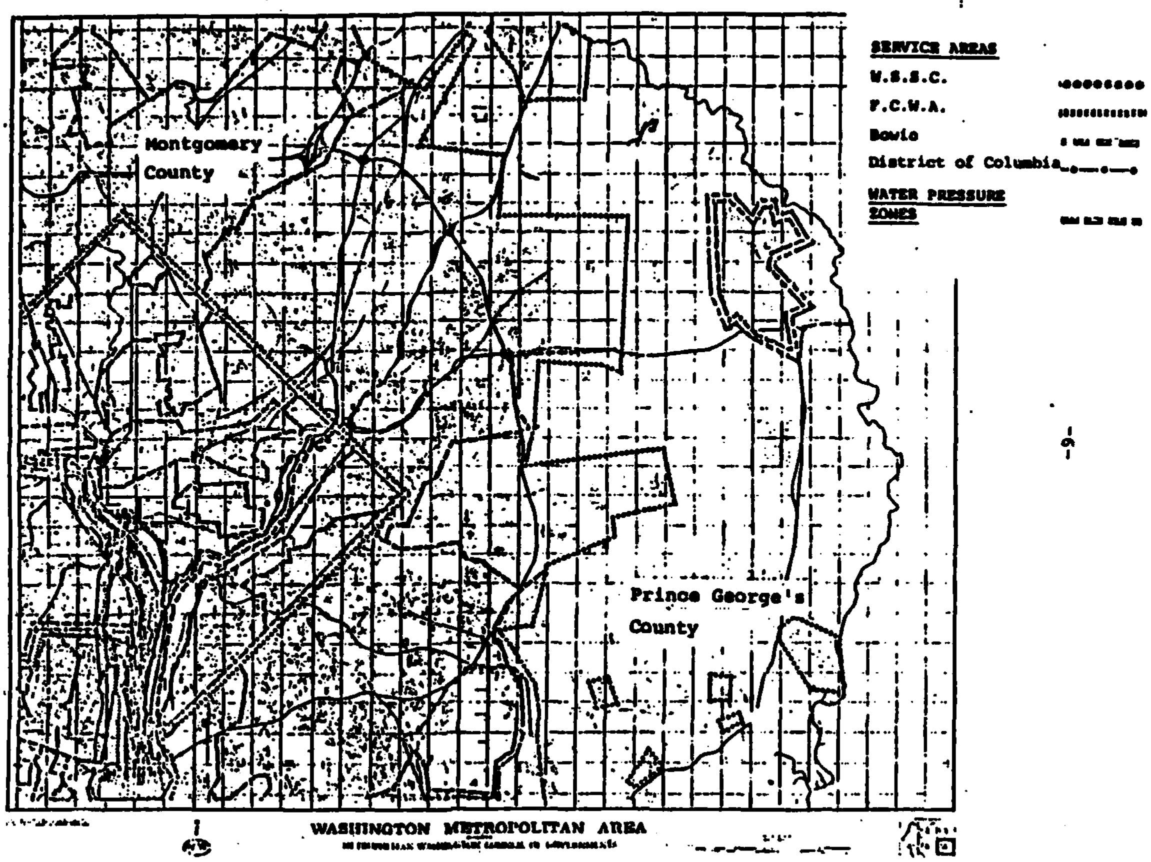
WASHINGTON METROPOLITAN AREA

Water Supply Service Areas and Pressure Zones

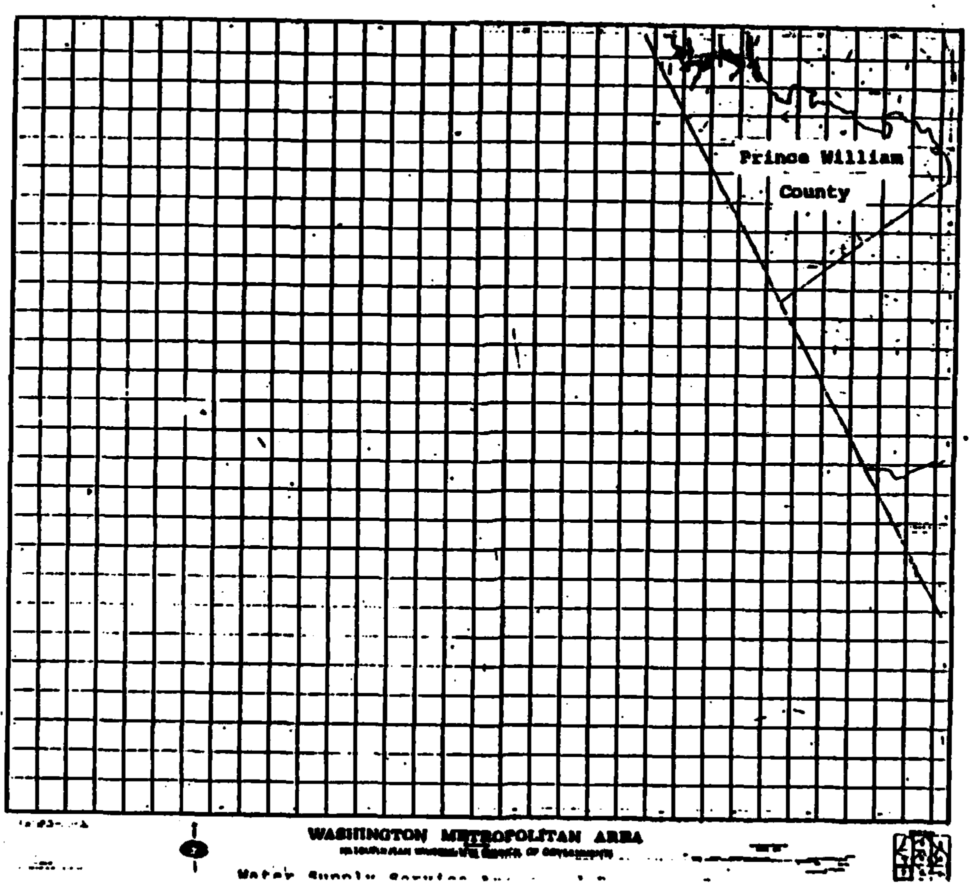


WASHINGTON METROPOLITAN AREA

-5-

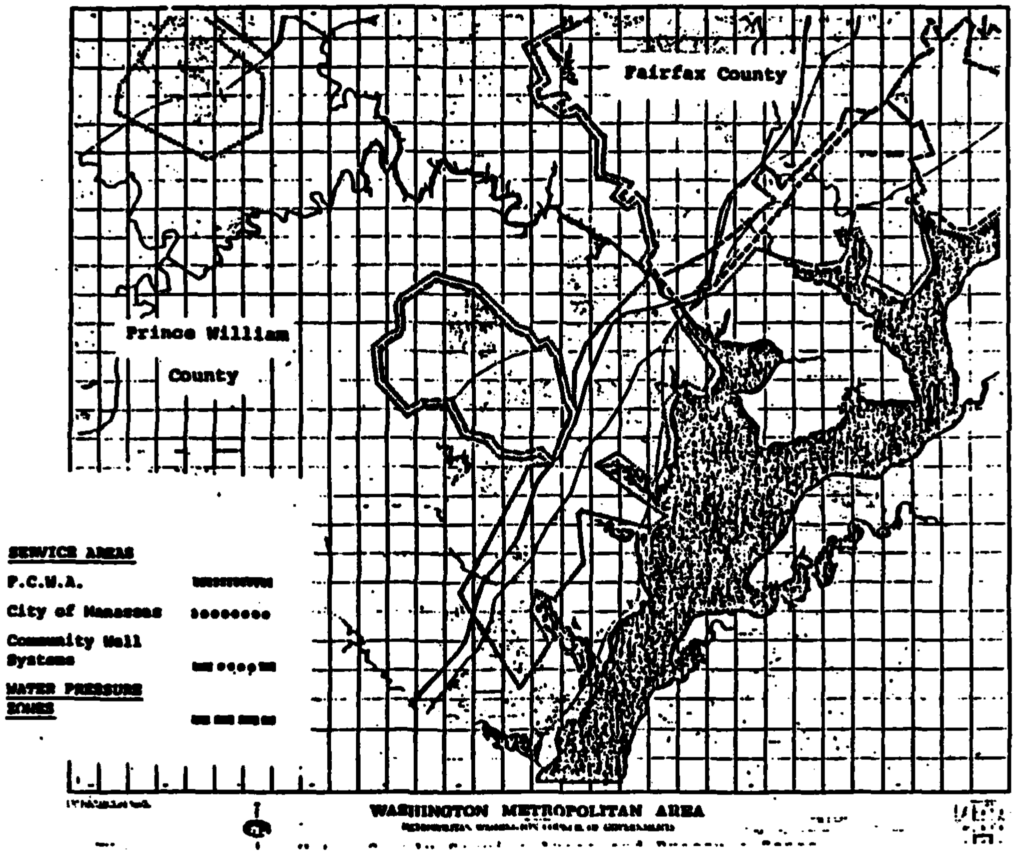

SERVICE AREAS
W.S.S.C.
F.C.W.A.
Bowie
District of Columbia
WATER PRESSURE ZONES
Montgomery County
Prince George's County
WASHINGTON METROPOLITAN AREA

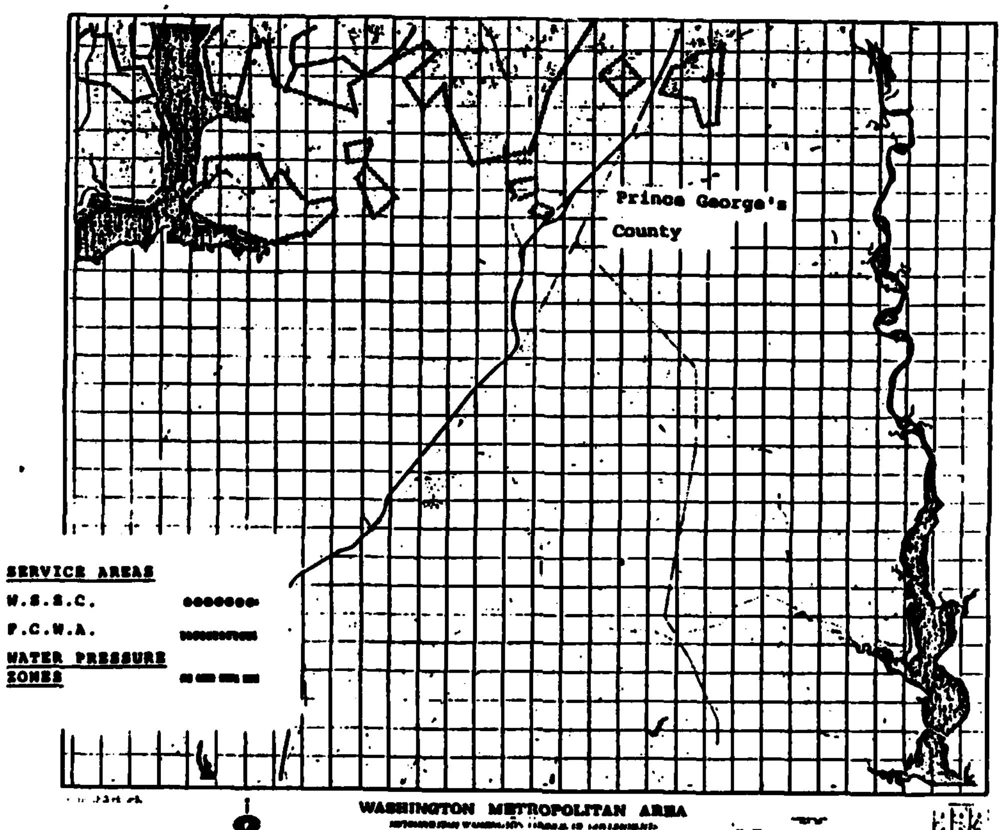
-6-


Prince William County
WASHINGTON METROPOLITAN AREA

-7-

G-I-37





Water Supply Service Areas and Pressure Zones

G-I-38

ANNEX F

FAIRFAX COUNTY

PROPOSED RESTRICTIONS ON WATER USE

(by Fairfax County Water Authority)

Water Supply Emergency Implementation Plan for Fairfax County, Prince William County and the City of Alexandria.

G-I-39

FAIRFAX COUNTY
PROPOSED RESTRICTIONS ON WATER USE

STAGE I

The public is requested to refrain voluntarily from watering lawns and other vegetation, washing automobiles, unnecessarily washing down driveways and sidewalks, and other uses of water hoses, and to conserve water from affected public water supplies in all other practicable ways. Due publicity will be given to the need for water conservation and suggested methods of conservation will be publicized.

STAGE II A

The purpose of Stage II A is to reduce water consumption with minimum hardship or economic loss to individuals and business concerns. Use of the affected public water supply for any of the following purposes is prohibited:

1. Watering of shrubbery, trees, lawns, grass, plants or any other vegetation, except from a watering can or other container not exceeding three-gallon capacity, excluding plant nurseries, golf course greens and commercial agricultural activities.

2. Washing of automobiles, trucks, trailers or other mobile equipment, except in vehicle wash facilities operating with a water re-cycling system approved by the County with a prominently displayed sign in public view so stating, or except from a bucket or other container not exceeding three-gallon capacity.

3. The washing of streets, driveways, parking lots, service station aprons, the exterior of commercial or residential buildings, or any other outdoor surfaces, except from a bucket or other container not exceeding three-gallon capacity, unless such washing is required to eliminate hazard.

4. Operation of any ornamental fountain or other structure making similar use of water.

5. Filling (from an empty or less than three-quarters full condition) of swimming and/or wading pools, except for home wading pools requiring not more than five gallons of water.

6. Service of drinking water in restaurants, except on request.

STAGE II B

In addition to those measures included in Stage II A, use of affected public water supply for any of the following purposes is prohibited:

1. Adding water to any kind of outdoor swimming and/or wading pools, or to fountains, reflecting ponds or other ornamental structures.

2. Any other use of water supply for outdoor recreation.

3. Air conditioning, where interior temperature is less than 78 degrees F.

STAGE II C

In addition to those measures included in Stages II A and B, the use of affected public water supply for any of the following purposes is prohibited:

1. Adding water to indoor swimming pools.

2. School athletic programs and other indoor athletic/recreation activities, including health spas.

3. Use of water from fire hydrants other than for health and safety purposes.

4. Use of water for construction purposes, including hydro-seeding, dust control and filling or flushing water mains for new developments.

5. Commercial vehicle and automotive equipment washing.

6. Watering of golf course greens.

STAGE II D

In addition to those measures included in Stages II A, B and C, use of affected public water supply for any of the following purposes is prohibited:

1. Make-up water for air conditioners.

2. Watering of plants by commercial nurseries and agricultural water users.

3. Use of automatic ice making machines in hotels and motels.

4. Production and bottling of beverages.

5. Operation of any commercial or industrial facility which is ordered closed by the local jurisdiction.

STAGE III

In addition to those measures included in Stage II, the use of water for any purpose not essential to life, health and safety is prohibited. Specific guidelines for water use will be promulgated before invoking Stage III restrictions.

ANNEX G-II

THE ROLE OF PRICING IN WATER SUPPLY PLANNING FOR THE METROPOLITAN WASHINGTON AREA

REPORT PREPARED BY JACK FAUCETT ASSOCIATES, INC.

THE ROLE OF PRICING IN WATER SUPPLY PLANNING FOR THE METROPOLITAN WASHINGTON AREA

VOLUME I

Submitted to:

U.S. ARMY CORPS OF ENGINEERS
Baltimore District

June, 1982

Submitted by:

JACK FAUCETT ASSOCIATES, INC.
5454 Wisconsin Avenue
Chevy Chase, Maryland 20815

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF EXHIBITS

LIST OF EXHIBITS (Continued)

LIST OF EXHIBITS (Continued)

LIST OF EXHIBITS (Continued)

I. INTRODUCTION AND SUMMARY

A. THE ROLE OF PRICING IN WATER SUPPLY PLANNING FOR THE METROPOLITAN WASHINGTON AREA

The history of water resources development in the Potomac River Basin includes many Congressional authorizations for individual studies, projects, and planning reports, dating from the 1800's to the present. Several of these studies are significant as they represent comprehensive basin planning efforts as well as individual projects for water resource management.

In July 1955, Congress authorized a study of the North Branch Potomac River for the purposes of flood control, low flow augmentation, and water quality control. The Bloomington Lake project was subsequently authorized by the Flood Control Act of 1962 as a result of this planning study. Located in Garrett County, Maryland and Mineral County, West Virginia, the project was completed in 1981. This is the only Federal project to be constructed from previous comprehensive studies.

In January 1956, a Congressional resolution was passed requesting the Corps of Engineers to prepare: "a comprehensive plan for the control of floods and the development and conservation of the water and related resources of the Basin, with emphasis on present and future needs for water supply and pollution abatement." This authority provided the basis for the comprehensive Potomac River Basin Study.

The Potomac River Basin Study (1), completed in February 1963, underwent many reviews and changes before being submitted to the Congress in 1970. The original plan which called for the construction of 16 major upstream reservoirs was ultimately reduced to two projects as a result of refinements in the technical studies and public opposition to many of the sites.

In reviewing the Secretary of the Army's recommendations for two upstream reservoir projects (Verona Lake and Sixes Bridge Lake), a 1972 Congressional Conference Report recommended that the projects be re-evaluated. The result of the reformulations was summarized in a document in 1973 entitled: Potomac River Basin Water Supply -- An Interim Report (2), in which three distinct recommendations were made: (1) the

authorization and construction of the reformulated Sixes Bridge Lake and Verona Lake projects for the purposes of water supply, recreation, and stream enhancement; (2) the authorization and construction of a prototype advanced water treatment plant (1 mgd nominal capacity) to test the feasibility of using the Potomac Estuary as a permanent supplemental water supply source for the MWA; and (3) the continuation of studies to prepare plans for meeting the water supply demands of the MWA.

A parallel study, published in 1975 by the Corps of Engineers, entitled the Northeastern United States Water Supply (NEWS) Study (3), also produced valuable information -- a series of general programs for water supply development in the northeast.

The Potomac River Basin Water Supply -- An Interim Report and the Northeastern United States Water Supply Study gain specific mention because their recommendations influenced the content of the legislation and direction for the present Metropolitan Washington Area Water Supply Study.

The Metropolitan Washington Area Water Supply Study was authorized by Section 85 of the Water Resources Development Act of 1974 (P.L. 93-251), which directs the Chief of Engineers to:

> *". . . make a full and complete investigation and study of the future water resources needs of the Washington metropolitan area, including but not limited to the adequacy of present water supply, nature of present and future uses, the effect water pricing policies and use restrictions may have on future demand, the feasibility of utilizing water from the Potomac estuary, all possible water impoundment sites, natural and recharged ground water supply, wastewater reclamation, and the effect such projects will have on fish, wildlife, and present beneficial uses . . ."*

In reponse to this mandate, the Corps Baltimore District Office began the Metropolitan Washington Area Water Supply Study. A Draft Progress Report (4) of this study was published in August of 1979. This report presented several alternative scenarios for water supply development. Earlier demand forecasts had been revised downward and the proposals for new supply projects had changed from large Federal impoundments to combinations of locally financed alternatives. The demand forecast was revised to take account of the effect of water conservation programs. The major new construction projects proposed consisted of a small reservoir, Little Seneca, and pipeline projects to interconnect Patuxent and Occoquan reservoirs with the Potomac.

A year later, the Baltimore District contracted with the firm of Jack Faucett Associates, Inc. to perform a study of the effect of water pricing policies on demand in fulfillment of the Congressional requirement cited above. At the outset it was generally suspected that the pricing study would show that demand forecasts could be further reduced by the implementation of better water pricing policies based on the economic concept of "marginal cost."

Shortly after the pricing study got underway, new research results were presented which changed the course of the pricing study and of the entire Metropolitan Washington Area Water Supply Study. Computer simulations by the Corps and others demonstrated that "supply management" techniques (strategies to optimize the joint use of regional facilities) could be used to greatly expand the capacity of existing water supply projects. This development required revision of the base case supply scenarios presented in the Draft Progress Report and also required a shift in emphasis regarding the alternatives to be considered in the Metropolitan Washington Area (MWA Water Supply Study.

The pricing study was at an early enough phase that it could be adapted to the new developments. The pricing study has now been completed and can be used as an input to the planning process. However, results of the pricing study are quite different from original expectations. The great capacity-stretching advantages of supply management have the effect of making new increments of capacity so inexpensive over the near-term that prices high enough to depress demand cannot be justified on the basis of marginal cost.

It may seem from these empirical results that pricing has no further role to play in water supply planning for the MWA. But in the course of the pricing study it became very apparent that the role of pricing is much broader. Pricing cannot be viewed simply as a factor to be considered in the development of a demand forecast. The theoretical analysis reported here shows that pricing policy is also a most critical factor in determining the benefit/cost ratio of regional water supply plans and in determining the best institutional arrangements for regional cooperation.

In commenting on the Draft Progress Report of the MWA planning study, the review committee of the National Academy of Sciences (5) urged the Corps of Engineers to perform a formal benefit/cost analysis of water supply plans and to thoroughly examine

different institutional approaches to regional cooperation. This report on the role of pricing in water supply planning provides important theoretical groundwork for benefit/cost analysis. In essence, the optimal benefit/cost ratio and the most equitable institutional arrangements can be determined only in the presence of optimal pricing policies. This defines the broader role of pricing in regional water supply planning.

Comparing the empirical conclusions of this study with the theoretical conclusions, it would appear that the Metropolitan Washington Area is confronted with a paradoxical situation. On one hand, better pricing policies based on marginal cost concepts were found to be inapplicable, over the near-term, due to recent developments in supply management. On the other hand, it was found that, over the long-term, the theoretically optimal schedule of regional water supply development (the maximum benefit/cost ratio) can only be realized if water pricing policies are based on the appropriate theoretical concepts (i.e., marginal cost).

The apparent conflict between empirical and theoretical conclusions may be resolved by recently proposed changes in the institutional arrangements that form the basis of cooperation between water utilities in the region. Revisions to the Potomac River Low Flow Allocation Agreement (LFAA), previously a device for allocating water between utilities, have been proposed which would incorporate a formula for allocation of the costs of new supply projects. In this revised form, both the water allocation formula and the cost allocation formula provide strong incentives to participating utilities to reduce peak demands. This new agreement has very optimal characteristics in the sense of econmic theory. Over the long term, as the initial benefits of supply management recede and the region again faces expensive new supply choices, this institutional mechanism will keep attention focused on pricing policy and reward pricing practices that approximate the theoretically optimal approach. This set of incentives should, in the long-run, assure optimal water supply development within the region (i.e., a maximum excess of benefits over costs).

This report presents both empirical and theoretical analyses of the role of pricing in water supply planning for the MWA. The major empirical and theoretical findings are summarized in the following two sections (B and C) of this chapter. Section D of this chapter provides a guide to the more detailed presentations in the body of the report.

B. EMPIRICAL FINDINGS

The empirical work performed in this study focused on the question, "Would better pricing policies produce a reduction in the amount of demand to be served by water supply plans?" This question stems from the notion that water prices have historically been too low. There are two major reasons why water prices are believed to be too low:

- the lack of accounting for the higher incremental costs of future capacity increases; and,
- the lack of accounting for the fact that peak period demand is the major cause of capacity increases.

Exhibit I-1 illustrates these points. In the left-hand side of the exhibit, the increasing cost of successive capacity increments is represented by the step-shaped curve. If a water utility charges the price p_1 at time t_1, consumption behavior will adjust to this price. An important aspect of consumption behavior is the rate of demand growth. There is something inherently wrong about allowing demand to grow based on price p_1 when the growth that results will produce a need for new capacity at time t_2 that will cost p_2.

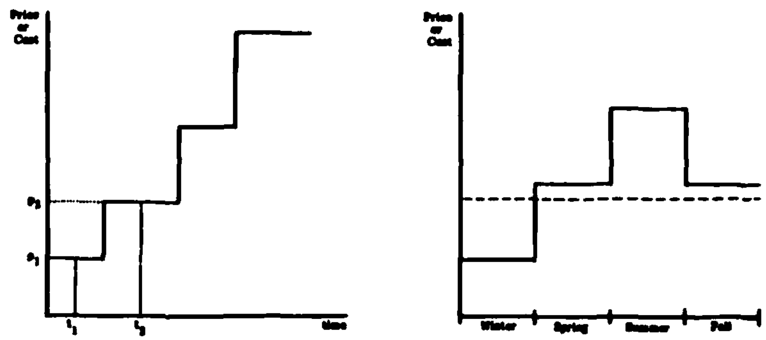


Exhibit I-1: EXPECTED RELATIONSHIPS BETWEEN COSTS AND RATES

This type of problem is brought about by the fact that most utility rate structures are based on the historical costs appearing on the accountant's books. The cost of new facilities is seldom factored into rate designs.

The right-hand side of Exhibit I-1 illustrates the seasonal pattern characteristic of water demand. The capacity required by a utility is determined by the quantity to be served during the peak summer season. As the diagram indicates, this peak demand is the most expensive portion of the demand to be served because the capacity is only used during one small portion of the year. Many water utilities, however, have historically charged a single year-round rate (dashed line in Exhibit I-1) which represents the "average cost." This averaging together of the four seasons spreads the high cost of peak period capacity throughout the year and results in a peak period price which is too low, encouraging excess consumption.

From the above observations, it seems obvious that if water prices are raised to account for both future costs and peak period costs; the result will be slower demand growth and less need for expensive new capacity. But there remains an unanswered question: how high should prices be raised?

Economic theory dictates that price should always be set equal to "marginal cost." For the moment, the marginal cost can be thought of as the amount necessary to account for the future costs and peak period costs described above. It is worthwhile to dwell on the economic significance of setting price just equal to the level of these costs. When this pricing practice is followed, economic theory guarantees that two objectives will be achieved:

- efficiency in the use of the resource: All consumption that contributes to the need for increased capacity will be undertaken only if the consumer is willing to pay the cost of new capacity.

- equity between users of the resource: Each consumer is assured of paying the full costs of his own consumption -- no more, and no less.

The central task of the empirical portion of this study was to develop estimates of marginal costs for utilities in the Metropolitan Washington Area. Using these estimates it was envisioned that a reduction in demand made possible by better pricing could then

be forecast. Somewhat surprisingly, however, the empirical results turned out quite different from these expectations. The reasons for the difference are illustrated in Exhibit I-2.

The left-hand side of Exhibit I-2 shows a downward-shifted cost curve (dashed line), signifying the effect of recent advances in techniques of "supply management." Supply management (optimizing the joint operation of regional water supply facilities) has had the effect of making new increments of capacity less expensive therefore making the inefficiency produced by ignoring future costs less extreme.

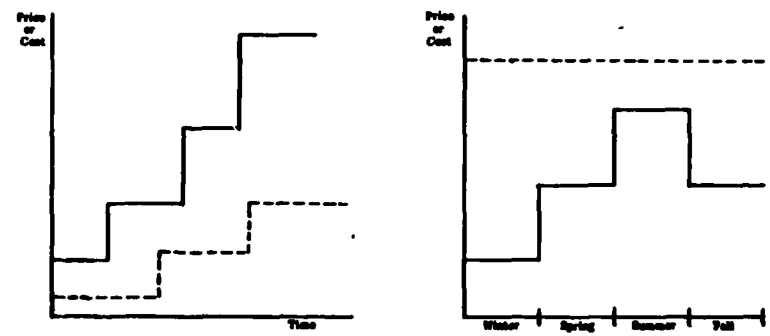


Exhibit I-2: ACTUAL RELATIONSHIPS BETWEEN COSTS AND RATES

The right-hand side of Exhibit I-2 illustrates a seemingly implausible circumstance in which the average annual rate currently being charged (dashed line) exceeds the marginal cost peak period rate. This is, however, the actual circumstance found to exist in the empirical results. There are two major reasons for this result:

- The reduced cost of new capacity made possible by supply management greatly reduces the price that should be charged for peak period consumption.

- Only costs that vary with consumption are included in the marginal cost estimates whereas the average annual charges used by many utilities also include "fixed costs," such as pipeline maintenance, that do not vary with consumption. In water and sewer utilities, fixed costs can be a very large proportion of total costs. Average annual rates are therefore higher than marginal cost rates.

The theory of marginal cost pricing is well-understood and has been used in numerous applications. There are, however, comparatively few cases where it has been applied to water utilities. It has been found that the concept may reduce demand in water-short areas such as Tucson (6) where the very high cost of new increments of supply more than offsets the high proportion of fixed costs included in present rates. Other studies, in places like Atlanta (6) and Washington, D.C. (7) have found that it is not possible to offset the high proportion of fixed costs in present rates.

The difficulty in offsetting the large proportion of fixed costs is especially great in those very few cases, of which this study is one, where both water and sewer pricing have been considered together. In most places, the water meter is used as a basis for sewer billing and, in many instances, a single bill is issued for both water and sewer service. Because the consumer often pays attention only to the bottom line, it is necessary to consider pricing policy for both services jointly. The inclusion of sewer costs detracts somewhat from the objectives of water pricing because new sewer capacity is the more expensive of the two; sewer service has different peaking characteristics; and, sewer service also entails a high proportion of fixed costs.

Before concluding that pricing simply does not work, it is appropriate to review various qualifications that are associated with these empirical results. A number of variables involved in the analysis are subject to change over time and it is a quite different conclusion to say that pricing does not work at the present time but may be worthwhile later on. The major areas of uncertainty include: order-of-magnitude input assumptions, cost estimates, and intangible costs not counted in the analysis.

The history of water supply planning for the Metropolitan Washington Area, outlined above in Section A, has been characterized by successive studies and refinements of the order-of-magnitude of the problem. Such refinements could be repeated again. Critical order-of-magnitude assumptions affecting the empirical analyses performed in this study include those pertaining to:

- the forecast of demand growth,
- the effectiveness of supply management, and
- the amount of Potomac supply allowed to "flow-by" the water intakes to preserve water quality.

As detailed in later chapters, the amount of "flow-by" was used as a test variable to perform sensitivity analyses on the empirical results. The sensitivity analyses indicate that it would take a major change (over 200 MGD) in these order-of-magnitude factors in order to produce a price effect on demand before the year 2000.

The primary task of the empirical portion of this study was the development of marginal cost estimates and forecasts for the ten Washington area utilities that use water from the Potomac. Estimating marginal costs for various aspects of water and sewer operations is complicated by a host of problems that make it difficult to force real-world cost data into the economist's theoretical concepts of cost. Estimates required for pricing analysis entailed some minute details and distinctions that are not common to the everyday needs of utility accountants and engineers. Thus, some important judgement calls had to be made, all of which are subject to some error. It is also likely that the utilities use various assumptions in their financial planning that differ from those employed in these analyses.

Overall, the error contained in the cost estimates is not thought to be severe. With all other things held constant, it would take a lot of error in the cost estimates to substantially change the viability of marginal cost peak period pricing before the year 2000. Cost forecasts up to the year 2000 are based on utility plans and regional planning studies and should represent the correct order of magnitude. After the year 2000, cost forecasts are, of course, less secure.

An important observation from the empirical results was that marginal cost peak period pricing seemed to come closer to working for the utilities which provided the most detailed cost data. It is concluded from this that perhaps the best way to monitor the effect of future changes in costs on the viability of pricing is for the utilities to incorporate more extensive detail in the way that they record and forecast costs. The present empirical study was designed as a first-cut broad sweep at estimating marginal costs for all ten utilities using the Potomac. A second-cut to further refine these estimates can best be undertaken by the utilities themselves on a continuing basis. In this way, the viability of pricing can be continually assessed as conditions change.

The "external" costs of expanding water and sewer capacity were, for the most part, not counted in the empirical analysis. These include the direct environmental impacts of building and operating water sewer facilities and the indirect environmental impacts of continued urban growth and development. Economists often refer to such impacts as "intangible" costs because they are difficult to quantify in dollar terms. It would be very legitimate from a theoretical standpoint to include an extra premium on the water bill to encourage consumers to reduce their consumption and thus mitigate environmental damages. However, it is extremely difficult to pick an amount for such a premium that everyone would agree with. Looking toward the future, these environmental values may become increasingly important due to the increasing scarcity of natural environments. This factor may then be sufficient to make the difference in a determination of the viability of pricing.

In consideration of all of the above-described sources of uncertainty affecting the empirical results, it is nonetheless safe to conclude that marginal cost peak period pricing is not a viable strategy for demand reduction before the year 2000. After that time, however, changes in any number of the variables involved could reverse this conclusion. It may therefore be very worthwhile to continually track these changes so that future opportunities will not be missed.

C. THEORETICAL FINDINGS

Utility pricing or rate setting may be thought of as a process of allocating costs among users. Economic theory provides an optimal prescription for performing this allocation. A reiteration of the efficiency and equity goals of theoretically ideal pricing will help to emphasize this point:

- <u>efficiency in the use of the resource</u>: All consumption that contributes to the need for increased capacity will be undertaken only if the consumer is willing to pay the cost of new capacity.

- <u>equity between users of the resource</u>: Each consumer is assured of paying the full costs of his own consumption -- no more, and no less.

This study was initially conceived with the notion that pricing could be used to depress the rate of demand growth and thus produce cost savings to the region. Empirical work focused on assessing the feasibility of using pricing policy to this end. However, the concept of cost allocation, identified above implies that pricing policy has a much broader role to play. Accordingly, the theoretical work addressed the question of defining this broader role and exploring its implications for regional water supply planning.

Exhibit I-3 is a schematic presentation of the cost allocation process in a regional context. In a regional program calling for cooperation between utilities, costs are allocated to users via a two-step process. First, regional cost-sharing arrangements determine the allocation between participating utilities. Then, rate structures of the individual utilities determine cost allocation to users.

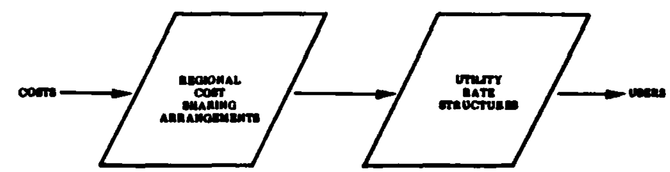


Exhibit I-3: TWO-STEP ALLOCATION OF COSTS IN REGIONAL WATER SUPPLY PLANNING

The study team was therefore faced with the problem of choosing a regional cost sharing formula in order to be able to evaluate utility rate structures. From the standpoint of economic theory, there is only one right way to allocate costs to users. Thus, it is appropriate for the economist to view regional cost-sharing arrangements between utilities as simply another rate setting problem. The study team assumed a regional institutional arrangement in which there is "one big utility" that oversees supply management operations and builds new capacity as needed. This hypothetical regional institution then allocates costs to the participating utilities according to the same economic principles of optimal pricing. The hypothetical regional authority was assumed empowered to levy a surcharge on every water bill in the region equivalent to the correct marginal cost peak period price.

In commenting on the Draft Progress Report of the Metropolitan Washington Area Water Supply Study (4), the National Academy of Sciences review committee (5) has urged the Corps of Engineers to investigate such regional institutional arrangements. It is important to have regional cost-sharing arrangements in which all users are charged the correct marginal cost peak period price because there is a direct connection in economic theory between benefit/cost analysis and the cost allocation principles embodied in the efficiency and equity goals of good pricing. Prices are used to help estimate benefits; and, if there is error in pricing policy then the entire benefit/cost analysis is also in error.

In the Draft Progress Report, benefit-cost analysis was replaced by cost-effectiveness analysis; benefits were assumed the same for all alternative plans and attention was focused on finding those which presented the least total cost. Regional cost-sharing arrangements between utilities and utility pricing policies, which together determine the benefit side of the benefit/cost equation, were assumed not to affect the analysis. The National Academy of Sciences (NAS) review committee offered the following critique of this procedure:

> *As the Corps study now stands, the use of the cost of any particular plan to estimate benefits rests on the following assumptions:*
>
> - *The plan is one that actually would be attempted in the absence of any Federal or Federally inspired action.*
> - *The plan is the least costly of any scheme that might be attempted.*

> - *The jurisdictional incidence of benefits must be substantially the same for all plans.*
> - *Future price levels must be substantially the same for all plans.*
> - *It must be assumed that each jurisdiction's willingness-to-pay for an increment of water supply is an adequate estimator of the aggregate willingness-to-pay at current rates by water users for the additional water to be provided.*

In essence, the only strategy that can maximize the excess of benefits over costs for the region as a whole is one which employs both optimal cost sharing arrangements between utilities and optimal pricing by all utilities. Quoting again from the NAS review committee:

> *Without benefit-cost analyses, the determination of the basis for possible regional cooperation (i.e., the optimum institutional arrangements) cannot proceed very far. Each of the parties affected tends to act in its own self-interest, recognizing its gains only in relation to its costs.*

The hypothetical regional cost sharing arrangements developed for purposes of this pricing study demonstrate the broader role of pricing in regional water supply planning as the underlying factor in benefit/cost analysis. The advantages of supply management may have, for the moment, limited the role of pricing as a strategy to reduce demand but supply management also brings with it an imperative need for regional cooperation. The cost allocation principles of good pricing are critical to the development of regional institutional arrangements.

If left uncorrected, the cost sharing formulas used in the Draft Progress Report would produce less than optimal plans for regional cooperation and water supply development. The formulas used in the Draft Progress Report were based on the Potomac River Low Flow Allocation Agreement (LFAA). This is a device for allocating resources among utilities during periods of extreme low flows in the Potomac. The LFAA water allocation rule allocates scarce peak period supplies on the basis of the offpeak demand levels of the participating utilities. This formula is very compatible with economic theory as it provides an incentive for the utilities to somehow control their peak period demands. In the Draft Progress Report, however, these water allocations were subsequently used as a basis for cost allocation between utilities. Certain geographic

constraints affecting the water allocations produced distributions of costs between utilities that are inconsistent with economic theory.

Since the Draft Progress Report, there have been two important new developments which will make it possible to avoid repetition of such errors in regional cost-sharing arrangements (and resultant errors in the regional benefit/cost ratio).

- Supply management, a technique for optimizing the joint use of all the water supply facilities in the region, has essentially eliminated the geographic constraints which affected cost-sharing arrangements in the Draft Progress Report.

- Very recently, the utilities in the region have been studying a proposed revision to the Low Flow Allocation Agreement which includes a cost-sharing formula that is very compatible with economic theory.

Under the proposed LFAA cost-sharing formula, the participating utilities will share in the cost of new facilities in proportion to their share of the growth in regional peak period demand. Initially, the cost savings produced by supply management may make the advantages of this new cost-sharing formula unnoticeable. As costs inevitably begin to rise again, however, this cost-sharing formula will automatically adjust the incentives facing the participating utilities. It will therefore not be necessary to conduct further studies to determine the point at which marginal cost peak period pricing becomes a viable strategy for reducing demand. As costs rise, a "reverse price war," fostered by the adjusting incentives, should evolve and proceed towards an equilibrium in which all utilities charge the correct marginal cost peak period price. With this mechanism in place, it seems assured that the maximum excess of benefits over costs can be achieved for the region as a whole.

D. GUIDE TO THE REPORT

The original draft of this report was written in a very technical fashion and comments received emphasized the need to clarify the presentation of theoretical points that are not readily understandable by non-economists. This report attempts to correct that problem, though sometimes at the expense of a great many additional sentences.

The report is organized into two main chapters following this one. Chapter II presents the theoretical analyses and Chapter III reports the empirical work.

Chapter II attempts to walk the reader all the way through the economic theory relevant to water pricing. It begins with a discussion of both the theoretical goals of pricing policy and those that are apparent from a non-academic, common sense perspective. It then proceeds to show the theoretical advantages of marginal cost peak period pricing in achieving these goals. Finally, the theoretical role of pricing in a regional water supply planning problem is considered in depth.

Chapter III begins with a summary section which presents and discusses all of the major empirical results. Ensuing sections of this chapter present the details of the methodologies employed in the empirical work. Appendices A, B and C (Volume II) present further supporting technical materials.

Appendix D (Volume II) summarizes the empirical results of a similar study of pricing policy that was undertaken for 12 smaller utilities in the Metropolitan Washington Area which do not depend upon the Potomac for their water supplies. All of the same analytical methodologies were employed in this study but the level of effort was considerably less than that applied in the main study.

II. THEORETICAL CONSIDERATIONS IN WATER PRICING

A. INTRODUCTION

There are numerous confluences between the way that water pricing is becoming popularly perceived and the pricing recommendations of economic theory. There are also some important divergences between the two. This chapter attempts to reconcile some popular common-sense notions of water pricing -- which are, in effect, theories of water pricing -- with the formal pricing theory of economics. It then goes on to describe the implications of pricing theory for regional water supply management.

Section B reviews a number of popular impressions of water pricing, including some specific ideas about the equitable allocation of costs and the prospects for much higher costs in the future. This section also reviews different ideas about pricing that have become the conventional wisdom among various groups involved in water supply planning. From the combination of perspectives, it is possible to define the overall societal goals of pricing policies. These concepts provide a common foundation by showing that all the different theories of pricing are intended to achieve the same objectives. It is on this basis that different approaches to pricing can be compared.

Section C presents the formal economic theory of peak period marginal cost pricing. The discussion explains why economists believe this approach is the optimal method for achieving the goals of good pricing. Section C also reviews each of the other commonly used utility rate structures and compares each to the economist's optimal approach. All of these alternate rate structures are shown to have theoretical deficiencies compared to the economist's optimal strategy.

Section D goes beyond the case of an individual utility to examine the theoretical role of pricing in regional water supply planning involving many utility service areas. The economic theory of pricing is shown to have significant implications for the design of regional institutional relationships as well as for the determination of regional capacity requirements.

In sum, this chapter presents the essential theoretical findings of this study. Great claims for the virtues of peak period marginal cost pricing may seem warranted on the

basis of theory. The reader is cautioned, however, that critical features of this theory are difficult to convert to practical application. Chapter III presents the empirical findings of this study and identifies a number of such problem areas.

B. POPULAR IMPRESSIONS AND ASSOCIATED "THEORIES" OF WATER PRICING

Perceptions of water pricing by both the public and professional groups have been changing throughout the 1960's and 1970's. The new awareness of pricing that seems to be emerging stems from some fundamental changes in the costs of providing water and sewer services. Because of the nature of public utility regulation, there is a direct relationship between escalation of costs and escalation of rates. Exhibit II-1 shows the recent time-path of water rates for several of the major utilities covered in this study. A steady upward trend is very evident in this diagram.

Exhibit II-2 presents data on the operation and maintenance costs of several study area utilities during recent years. The upward trend in these operating costs is most often attributed to the effects of inflation on such inputs as labor and to extreme rises in the cost of energy inputs required for pumping.

Steady rises in the costs of capital facilities are believed to be of even greater significance. Escalation of these capital costs is attributed to the following:

- New construction for both water and sewer has been needed to replace some older, worn-out capacity
- New water and sewer capacity has been needed to keep pace with urban growth
- Capital improvements have been needed to upgrade facilities to meet EPA criteria
- Inflation of construction costs has made new capital projects, such as the above, more expensive

The outlook for the future promises further increases in capital and operating costs due to these same causes. In addition, the major water suppliers dependent on the Potomac River are faced with the problem of having to somehow increase the capacity of this water source. The conventional wisdom according to economists and water supply

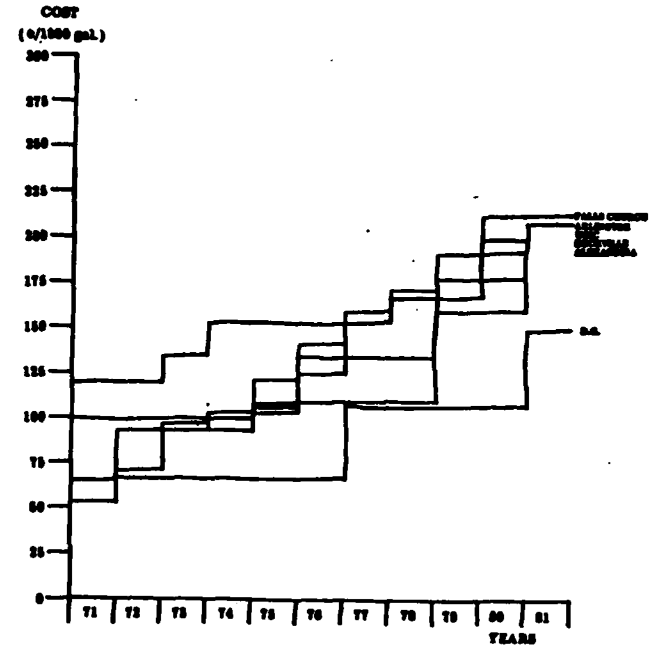


Exhibit II-1: RECENT HISTORY OF WATER AND SEWER RATES FOR SELECTED UTILITIES

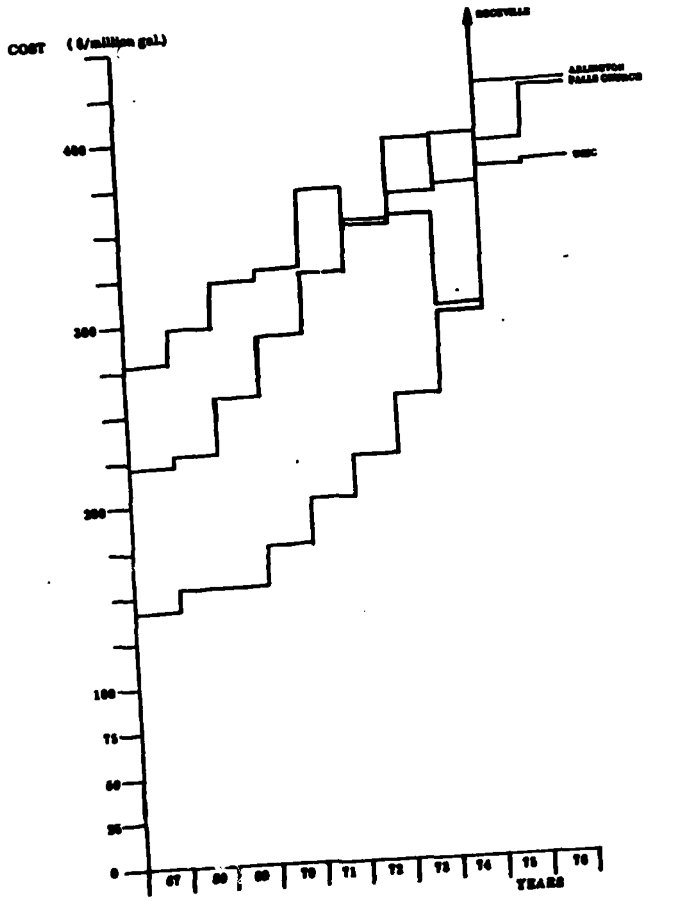


Exhibit II-2: *RECENT HISTORY OF O&M COSTS FOR SELECTED WATER UTILITIES*

planners holds that development of new water source capacity in urban areas will be an increasingly expensive proposition. As nearby and easily-developed options are used up, more remote and expensive supply alternatives must be turned to for new capacity. This future prospect can be visualized by a marginal cost curve like the one given in Exhibit II-3. This diagram shows cost vs. time rather than the traditional display of cost vs. quantity. The implication is simply that quantity increases over time due to demand growth. *The costs shown are 1980 "constant dollar" costs; that is, the cost data have* been adjusted for relative inflation in later facilities so that the diagram illustrates not only the higher cost of new capacity but also the exacerbating effect of continued inflation upon this trend. All future points on the curve represent the value of future investments from our current vantage point. For example, something that costs $100 (in 1980 dollars) in 1985 might cost $125 (1980 dollars) in 1990 due to relative inflation. This effect of inflation is built into the marginal cost curve of Exhibit II-3. A major task of this study was to estimate such curves for water supply source development and for all other water and sewer operations of the utilities studied.

Witnessing these recent trends in water and sewer costs and rates, many interested public and professional groups have begun to examine the possibility that pricing may be a means of controlling the cost spiral. A popular "pricing theory" holds that if prices are significantly increased, demand for water will decrease and the rate at which expensive new capacity is required will be slowed. In other words, the curve in Exhibit II-3 will not rise as steeply as before. The effectiveness of this strategy, however, is contingent upon the responsiveness of water demand to price changes -- the economist's concept of the "elasticity" of demand. Perceptions of this aspect of water demand have also been changing in recent years.

Water has often been given as a textbook example of a particular class of goods which are characterized by almost completely "inelastic demand." It is postulated that demand is not very responsive to changes in price (it is inelastic) for such commodities because they are viewed as necessities by the consumer and require only a negligible fraction of the consumer's income. From the inflationary events of the 1970's and the cost outlook for the future, many observers express the feeling that textbooks should henceforth choose a different example of such a good. The popular impression is that water and sewer costs and rates will escalate beyond some critical level afterwhich the consumer's response to the water bill will become more and more like that for the electric bill (more elastic).

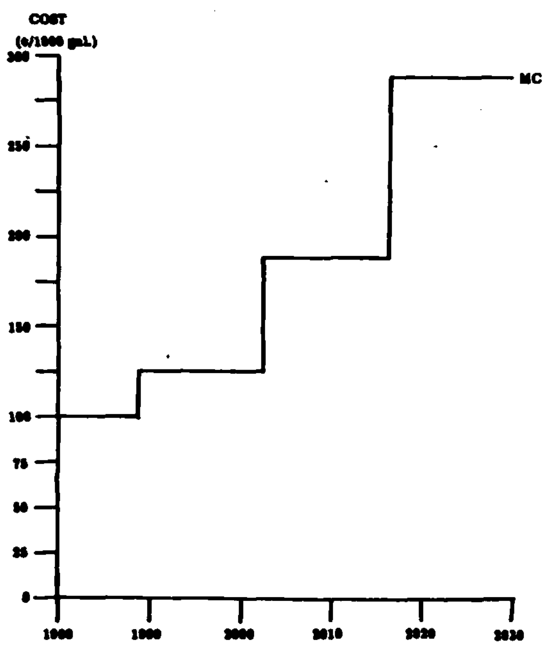


Exhibit II-3: ILLUSTRATIVE LONG-RUN MARGINAL COST FORECAST IN CONSTANT DOLLARS

Despite the general feeling that prices are moving toward a range where demand will be more elastic, the degree to which this will happen is unknown. As a result, there is still considerable uncertainty regarding the effectiveness of pricing as a strategy for reducing demand. Other issues surrounding the use of pricing to reduce demand include: the impact on low income families, the equitable distribution of the cost burden between different types of users, and the most effective way to assure savings in capacity costs. The views of several different public and professional groups on these and other related issues are characterized in the next few subsections.

1. Public Attitudes

Congress specifically directed the Corps of Engineers to conduct this study of Potomac River utilities to assess the role of pricing in planning new water supply capacity. The objective was to investigate the effectiveness of pricing for reducing demand as a non-structural alternative to building new supply capacity. Many environmental interest groups in the region support the view that using pricing to induce conservation is preferrable to building new reservoirs or other structural alternatives. Thus, there is a popular perception that pricing of water can be used as a tool for minimizing the environmental impacts from water supply construction projects. Some environmentalists also hold the view that environmentally damaging suburban sprawl has been encouraged by low water and sewer rates that do not reflect the full environmental costs of expansions in water and sewer capacity. On this point, some consumer groups might agree from the standpoint that charges levied on new connections should reflect the higher costs of new facilities and that existing customers should not have to shoulder any of this burden.

Consumer advocates may or may not agree with the concept of pricing to induce conservation. On the one hand, pricing for conservation may have some appeal to consumers as a means of economizing on expensive new facilities, producing lower rates over the long run. On the other hand, higher prices and coercive conservation measures impose an extra burden on consumers which may not be equitably distributed and may impose hardships on low income groups.

2. Utility and Corps of Engineers Perspectives

As the entities responsible for capacity planning, the perspectives of utility and Corps of Engineers analysts have certain similarities. First and foremost, planners who are accountable for providing sufficient capacity to meet demand are inclined to be skeptical of the reliability of pricing during peak periods. Utilities are chartered to provide adequate service to customers and there could be public health risks entailed in the event of a significant shortage. This uneasiness on the part of the planners is essentially a reflection of uncertainty over the responsiveness of demand to price changes (the elasticity of demand).

Another concern, particularly of utility planners, is the effect of inflation on construction costs. If pricing induces conservation and delays the need for new capacity, will this produce a cost savings or will further inflation produce the reverse result? This is a very tricky trade-off to evaluate, as discussed in Chapter III.

3. Rate Analyst and Economist Perspectives

The utility rate analyst and the economist have in common an understanding of some of the flaws of conventional approaches to pricing. The most basic problem that both economist and rate analyst perceive is that many popular rate structures underprice water during peak periods and encourage waste that contributes to rapid growth in the demand for new capacity. It is felt that higher prices for peak users will restrain demand and produce important financial benefits in reducing capacity requirements.

Disagreement between rate analyst and economist often centers about the question of how to assign the higher prices. Innovative conservation-oriented rate structures developed by utilities in recent years have tended to focus on charging higher rates to large volume users; the rate charged increases with the quantity consumed. Economists, on the other hand, argue that pricing should focus on the time of use rather than the volume of use; peak period rates should be used to distribute the high cost of peak capacity to all who demand peak period water.

4. The Goals of Pricing

After reviewing, in the preceding sections, various perspectives on water pricing it becomes apparent that all observers regard pricing, in theory, as a means of achieving the same basic objectives. The extent to which these goals of pricing can be achieved in practice, or the best approach to achieving them, are questions that form the substance of most issues surrounding pricing. The two major goals of pricing that underlie the discussion in the preceding sections are efficiency and equity. These may be further characterized, going beyond the definitions given in Chapter I, as follows:

- Efficiency -- making the best use of resources, thus minimizing unnecessary resource requirements; providing a given quality of water service at least cost to society.
- Equity -- (1) making sure that everyone pays the fair cost of their own consumption; no more and no less. (2) trying to avoid regressive effects that may impose undue hardships on low-income consumers.

These fundamental goals of pricing are the same for all types of pricing strategies. The underlying concepts of efficiency and equity are implicit in all water management issues and in all points of view. In any approach to pricing, the important issues often revolve around relationships between these two goals. Other issues arise in relation to consideration of:

- administrative complexity -- ease of administration and consumer understanding.
- system reliability -- can pricing really provide assurance against peak shortages?
- cost recovery -- the constraint that utilities cannot operate at either a deficit or a surplus, but must equate revenues with costs.

These factors are sometimes classified as additional goals of pricing, however, it is also appropriate to view them as constraints on the levels of efficiency and equity that are attainable.

Section C, which follows, presents the formal economic theory of peak period marginal cost pricing. The section explains, for the case of a single utility, that this approach to pricing possesses a theoretically optimal mix of efficiency and equity characteristics. Other pricing strategies are compared to this optimum and shown to be inferior. Section D expands the theoretical treatment to the regional level, showing further efficiency and equity aspects of pricing and covering issues of system reliability and environmental impact. Administrative complexity and cost recovery are discussed in the empirical presentations of Chapter III.

C. WATER UTILITY PRICING STRATEGIES

1. Rationale for Peak Period Marginal Cost Pricing

The economists' concept of peak period marginal cost pricing can be shown to be theoretically superior to all other approaches to water pricing. The theoretical rationale for this approach is presented in this section as a means of explaining the theoretical concepts against which other pricing strategies will be measured for comparison in Section C.2. which follows.

Economics is a theory of how best to allocate scarce resources among competing uses. The basic allocation rule is that scarce resources should be allocated first to those markets where they are most highly valued by society and then to less valued uses in descending order of priority. This is the underlying concept behind the familiar supply and demand curves shown in Exhibit II-4.

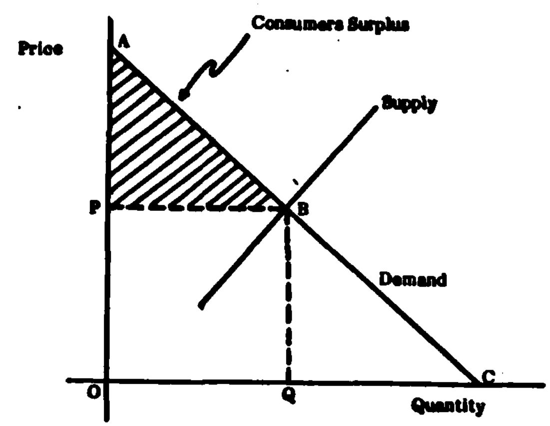


Exhibit II-4: SUPPLY AND DEMAND CURVES

The demand curve represents the amounts that various consumers are willing to pay for given quantities of the good. The total value placed on the good by consumers is represented by the total area under the demand curve (the triangle OAC). The supply curve represents the resource cost of producing the good. The optimal price (P) for the good is determined by the intersection (B) of the supply and demand curves. At price P, quantity Q will be purchased.

The revenue brought in by suppliers equals P times Q, which is equivalent to the area of the rectangle OPBQ. The area OABQ represents the total value of quantity Q to consumers. It is evident that the total value to consumers OABQ exceeds the revenue of suppliers OPBQ by an amount represented by the triangle PAB. This triangle is called the "consumers surplus" and reflects the fact that consumers get a bargain; they are charged only the resource cost of the good (price p), yet they are willing to pay much more.

The optimal price is seen to exist at the intersection B because it is at this point that the willingness to pay (demand) and the resource cost (supply) are just equal. Below this point on the demand curve additional units are demanded only at prices below the resource cost of the good. From the suppliers viewpoint it is not worthwhile to produce a good at less than its resource cost (resource cost includes return on investment to the supplier). If the same resources can be used to make other goods that can be sold at a price equal to the resource cost, then the supplier will switch to production of the other goods. This behavior on the part of suppliers is socially beneficial because it assures that resources are always allocated to the most highly valued uses. The value of a resource in an alternative use is called its "opportunity cost." The basic allocation rule of economics introduced at the beginning of this discussion may be restated: Whenever the opportunity cost exceeds the value of the resource in its current use, a re-allocation of resources is called for.

This theory is exciting to economists because it shows how an ideal allocation of society's resources (assuming, for theoretical purposes, no inequities in the distribution of income) can be brought about by simply allowing the price mechanism described above to function freely. In the theoretical ideal, the resulting allocation of resources in the economy is called "optimally efficient." The economists' concept of "allocative

efficiency" defines a state in which all of society's resources are allocated to their most highly valued uses. This results in the production of the most highly valued combination of outputs (GNP) for the given level of resources. This corresponds to the common-sense notion of efficiency as the attempt to maximize output from given inputs.

At the level of the firm, the role of price is to encourage optimally efficient use of resources in the firm's production processes. This efficiency can be assured by the presence of competitors who may be able to charge lower prices if they can find more efficient (less resource intensive) means of production. Water and sewer services, however, are "natural monopolies." A natural monopoly is a situation in which it is not efficient to have competitors due to the expense of duplicating expensive infrastructure such as pipeline networks under city streets. The occurrence of a natural monopoly is termed a "market failure;" the market mechanism fails to produce an optimally efficient use of resources because of the absence of competitive pressure on prices. For this reason, water and sewer services are provided by public utilities or regulated private companies under the control of a regulatory commission.

From an economic standpoint, the central problem in this type of public utility regulation is choosing levels of price and output that best approximate conditions that would exist if the market were competitive; thus reproducing the efficiency characteristics of competitive markets. The usual practice in public utility regulation, however, is that utilities are chartered to provide <u>reliable</u> service at a price sufficient to cover cost. The emphasis on reliability often results in determining output requirements first (based on peak demand) and then setting price sufficient to recover that level of cost. This tends to produce an inefficient situation of overcapacity because the costs of the peak capacity are generally spread over all annual consumption, causing peak use to be priced below its true cost. This underpricing further encourages peak consumption, promoting the need for still more capacity.

The utility pricing approach most favored by economic theory is "peak period marginal cost pricing." In theory, it can deliver an optimally efficient allocation of resources in water supply. The fundamental principle of this approach is the recognition that while the supply component of the market mechanism may be flawed due to the existence of a natural monopoly, the demand component is unaffected by this and can be used to produce an efficient solution. If a peak period price is charged which is equal to the opportunity cost of peak capacity, then the intersection with the demand curve will determine the optimal level of output automatically.

The "marginal cost" represents the opportunity cost of the resources required to provide water in peak periods. The "marginal cost" is the cost associated with the last unit of a good to be produced at the peak period level of output. This is generally the most expensive unit of the good produced. In the case of water supply, maximum demand for water usually occurs in the summer and the extra facilities needed to meet this demand represent the marginal cost of peak period water.

If water users are not willing to pay this marginal cost rate, then these resources should be shifted to other uses in other sectors of the economy where they can command prices reflecting their true economic value. In this way, marginal cost pricing helps to assure the optimally efficient rate of expansion of water supplies. Expansion of water supplies is due mostly to growth in peak use and growth in urban/suburban development. Marginal cost prices can assure that new projects built to serve peak demand are justified and that the rate of capacity growth is warranted.

2. Comparison of Alternative Rate Structures

a. Obsolete or Inapplicable Rate Structures

There are two types of rate structures which were historically very predominant in the water industry but are, for the most part, inapplicable to the current situation in major urban areas such as Washington, D.C. The "flat rate" is a fixed charge computed by dividing total costs by the number of customers. It was used mostly in the period before there was metering of water consumption. Because the flat rate is a fixed charge, it amounts to a declining rate per-unit of consumption; for each additional unit consumed, the cost-per-unit represented by the total bill is lower. The "declining block rate" is another rate structure which achieves the same effect a bit more intentionally by charging lower rates as consumption increases.

Both of these rate structures were used in earlier periods of urban growth when nearby sources of water supply were much more abundant and easily developed. The development of these readily accessible supply sources generated considerable "economies of scale" (opportunities to produce a good at very low unit cost when the volume of production is very large). This situation is described as a "declining cost industry" because the unit cost that must be recovered declines as the number of units consumed increases. From an economic standpoint, it is appropriate to reap the benefits of such economies of scale and declining rate structures work toward this end.

Exhibit II-5 shows the long-run cost curves characteristic of such a declining cost industry. The long-run marginal cost curve (LRMC) represents the full "opportunity cost" of the resources required to provide each additional increment of water supply. The long run average cost curve (LRAC) represents an average cost-per-unit at different levels of consumption. Because of economies of scale, the marginal cost curve is initially lower than the average cost curve and both curves are declining.

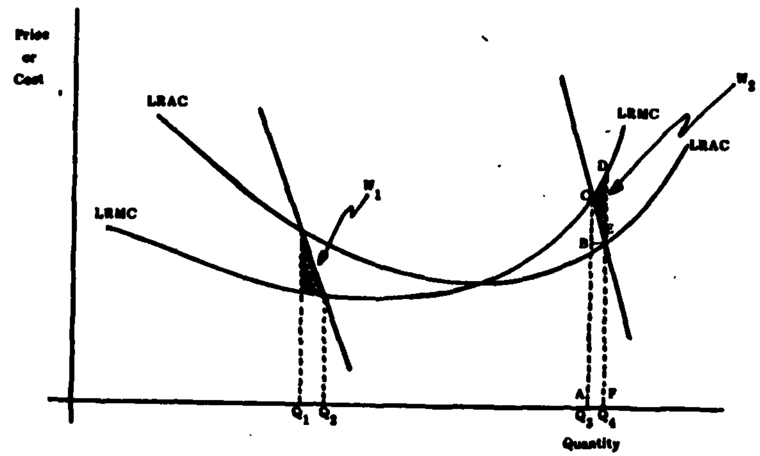


Exhibit II-5: EFFICIENCY CHARACTERISTICS OF DECLINING BLOCK AND FLAT RATES

In the absence of declining rate structures, utility rates would probably have approximated average cost due to the accounting ease of this concept. The economist, of course, always recommends setting price equal to marginal cost. From the diagram in Exhibit II-5, it can be seen that a switch from average cost to marginal cost prices produces a lower price and an increase in consumption from Q_1 to Q_2. At the Q_2 level of consumption, the "consumers surplus" is made larger by an amount equal to the area of the triangle labeled W_1. Thus, there is an improvement in economic efficiency produced by rates below the average cost. Declining rate structures may produce some of this type of benefit in this situation.

The current situation of urban water companies, however, is better represented by the right-hand side of Exhibit II-5 where long run marginal cost exceeds average cost. As nearby and easily developed water sources were used up, more expensive water supply options have had to be exercised in many major metropolitan areas, causing marginal cost (the cost of the last increment) to rise.

Declining rate structures are not applicable to the current situation. In fact, any price lower than the marginal cost produces a loss of economic efficiency. The loss associated with an average cost pricing policy, for example, is represented by the area of triangle CDE in Exhibit II-5. In this diagram, the opportunity cost of the increment of consumption between Q_3 and Q_4 is given by the total area ABCDEF. The revenue collected by the utility under average cost pricing equals (price times quantity) the area ABEF. The consumers surplus equals the triangular area BCE. It is seen that the combined areas represented by the revenue and consumers surplus fall short of the total economic value of the water (ABCDEF) by an amount equal to the triangle CDE. This means that the resources required to produce the water are being under-valued. Hence, the efficiency of the overall economy might be improved by allocating these resources to some other use. The amount of the efficiency loss is equal to the amount of the missing valuation -- the triangle CDE.

Despite these obvious inefficiencies, declining block rate structures continue to persist in many places. A number of the smaller utilities serving the outlying areas of the Washington, D.C. metropolitan region have such structures. In some cases, ample supplies of high quality well water coupled with the desire to attract economic development may justify the practice. However, for the larger Potomac-dependent utilities serving the central urbanized portion of the Washington, D.C. area, declining rate structures are not applicable to current circumstances.

b. Uniform Vs. Peak Rate Structures

Current circumstances in most urban areas are characterized by an increasing long-run marginal cost for new water supply source development; the last increment of capacity is becoming more and more expensive as cheaper sources are used up. In this type of circumstance, attention should be focused on the peak water demand period which occurs in the summer season. The peak demand to be served determines the peak capacity required. As demand grows, it is this peak capacity requirement that forces a decision to build additional increments of capacity.

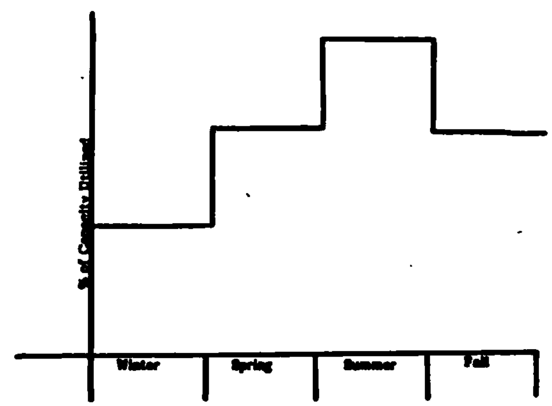


Exhibit II-6: SEASONAL VARIATION IN CAPACITY UTILIZATION

Exhibit II-6 presents a generic illustration of the seasonal variation in the level of capacity utilization that is characteristic of water utilities in the Washington metropolitan area. As shown, there is a significant proportion of total capacity that is utilized only during the summer season. Any reduction in peak demand, therefore, could obviate the need for the most expensive increments of capacity. Thus, control of the peak demand can be an attractive strategy for controlling escalation in utility costs. But is it optimal to do this from the standpoint of economic efficiency? And, if so, how should it be done? These questions can be examined by comparing peak period pricing with a uniform rate structure that does not distinguish the peak period. This comparison is made in Exhibit II-7.

In Exhibit II-7, the uniform rate is represented as the horizontal average cost curve (AC). Uniform rates are very often equivalent to average cost because this is the simplest uniform rate to calculate (total cost divided by gallons sold), given that public utilities are constrained to equate total revenues to total costs. The step-shaped curve in the diagram represents the marginal cost curve (MC). The lower step represents the

marginal cost of offpeak capacity and the upper step represents the marginal cost of peak capacity. According to economists, this marginal cost curve is the best guide to use in setting rates for a peak period rate structure.

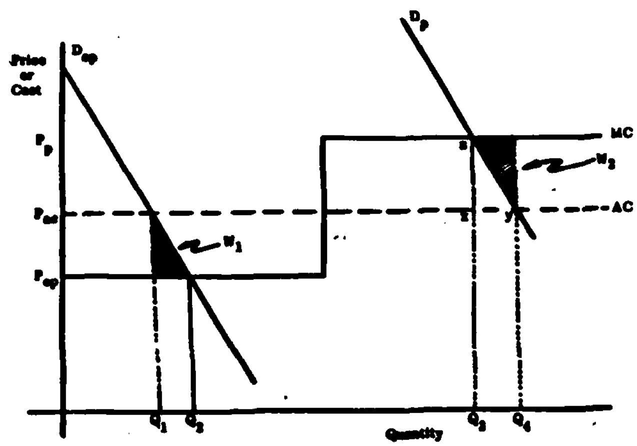


Exhibit II-7: EFFICIENCY CHARACTERISTICS OF UNIFORM OR AVERAGE COST RATES

The intersections of the peak and offpeak demand curves with the two different cost curves shown in Exhibit II-7 permit a more formal theoretical comparison of uniform and peak period rate structures. In the offpeak period, the average cost is well above the marginal cost. The uniform average cost rate limits the offpeak quantity demanded to Q_1. Under the marginal cost offpeak rate, consumption would increase to quantity Q_2. The triangle labeled W_1 represents consumers surplus which is lost under the uniform average cost rate.

Under the marginal cost offpeak rate, there is no such loss of consumers surplus. In fact, it can be shown that the marginal cost is the only offpeak rate for which there is no such loss of economic efficiency. Any offpeak rate represented in Exhibit II-7 by a horizontal line above the offpeak marginal cost will intersect the offpeak demand curve in such a way as to produce a triangle similar to W_1. By the same token, it is clearly not efficient to consider offpeak rates below the offpeak marginal cost as this would amount to selling water for less than the true value of the resources required to produce it.

On the right-hand side of Exhibit II-7, the marginal cost peak rate is shown to be well above the uniform average cost rate. Under the marginal cost peak rate, the intersection with the demand curve is held to the Q_3 level of consumption. At this level, the resource costs of the peak capacity are just equal to the willingness to pay. At all peak prices below this level, of which the average cost rate is one, peak consumption will be expanded to a quantity such as Q_4. This level represents peak consumption of water in excess of what is economically efficient. The full opportunity cost of the extra increment of capacity required to go from Q_3 to Q_4 (represented by the area under the marginal cost curve between Q_3 and Q_4) is not recovered by the average cost rate. Revenue is equal to the rectangle Q_3xyQ_4. Consumers surplus is equal to the triangle xyz. This leaves the triangle W_2 unaccounted for, indicating an economic loss. It can be shown, as in the case of the offpeak marginal cost rate, that such a triangle representing economic loss will be produced for any rate below the marginal cost peak rate.

In summary, the common-sense of this comparison of average cost and peak period marginal cost rates is that average cost rates "average-in" the high cost of the most expensive increments of capacity. With a uniform rate structure, this has the effect of making offpeak prices too high and peak prices too low. As a result, offpeak users end up subsidizing a considerable portion of the cost of peak capacity while peak users pay a price that is too low, encouraging them to consume excessively. The effect of the incorrect price signal given to peak users is particularly important because it accelerates the rate at which capacity must be expanded, adding increasingly expensive increments.

c. Price Discrimination

"Price discrimination" is said to exist whenever two customers are charged different prices for the same product and there are no differences in the cost of providing the product to them. Several rate structures designed to promote water conservation fall into this category. The Washington Suburban Sanitary Commission (WSSC) and a few other utilities in the Washington, D.C. area have instituted "increasing block" rate structures in which the rate charged increases with the amount of water consumed. The idea is to encourage water conservation by "discriminating" against users who demand large quantities. The Fairfax County Water Authority (FCWA) has developed a unique rate structure which discriminates against high volume users only during the summer season.

Both the increasing block and the Fairfax type of rate structure have the effect of encouraging conservation in peak period high volume uses such as lawn sprinkling. The economist must argue against such discrimination. To obtain optimal efficiency all peak uses must be charged at the same rate. This is necessary because the economic value of the last increment of capacity built to serve the peak is the same irrespective of the type of use.

For example, if a utility could avoid building an expensive increment of capacity by a one million gallon demand reduction during the month of August, the cost savings to the utility would be the same regardless of whether the demand reduction came from restrained lawn sprinkling or from restraint on the part of people who normally take long showers. This cost savings to the utility represents the opportunity cost of peak period water use to society. If the utility did not have to spend these resources on peaking capacity, the same resources could instead be applied to society's next highest purpose. Since all peak consumption imposes the same cost on society, all must be charged at the same rate.

Peak period rates designed according to this opportunity cost doctrine will probably produce reductions in many of the same uses that are targeted by price discrimination (lawn sprinkling, car washing, etc.). The key difference in this respect is that the economist's approach leaves it entirely up to individual consumers to determine their most important uses of water during the peak period. This difference is very important in terms of economic efficiency. The significance can be explained with the help of the diagram in Exhibit II-8.

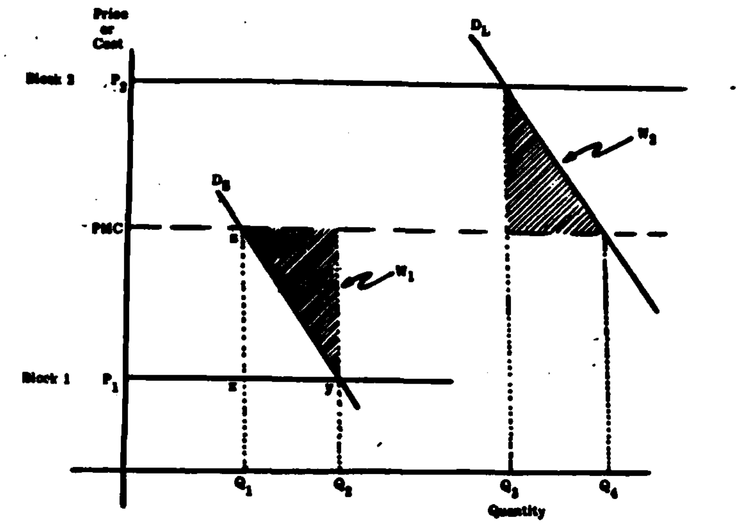


Exhibit II-8: EFFICIENCY CHARACTERISTICS IN PRICE DISCRIMINATION

For purposes of exposition, a simple increasing block rate structure is assumed, having only two blocks; Block 1 charging price P_1 to small volume users, and Block 2 charging the higher price P_2 to large volume users. The horizontal line emanating from the point PMC represents the marginal cost of water during the period being examined. The position of PMC between P_1 and P_2 is based on the assumption that the marginal cost will fall somewhere within the range covered by the block structure.

The intersection of the Block 1 rate with the small user demand curve shows that consumers in Block 1 consume quantity Q_2. The intersection with the marginal cost curve PMC shows that consumption by small volume users should only be quantity Q_1. The full resource costs of the quantity between Q_1 and Q_2 are not reflected in the P_1 price. The opportunity cost of the consumption between Q_1 and Q_2 is represented by the entire area under the marginal cost curve. The P_1 price does not produce a sufficient total of revenue (area Q_1xyQ_2) and consumers surplus (triangle xyz) to equal the area representing the value of the resources. The triangular area labeled W_1 remains unaccounted for and indicates a loss of economic efficiency.

The intersection of the large user demand curve with the Block 2 rate shows that consumption by large users will be restrained to quantity Q_3. At the marginal cost price, quantity Q_4 would be consumed. Thus, the block rate deprives large volume consumers of a consumers surplus equivalent to the area of the triangle labeled W_2.

d. *Summary Comparison of Alternate Rate Structures in Terms of Equity and Efficiency*

The preceding analysis of alternate rate structures has demonstrated a consistent relationship in economic theory between efficiency in resource allocation and the equity in cost allocation. In all of the various approaches to rate-making, the message that comes through repeatedly is that if all water users are faced with prices that reflect the true social cost of their own consumption, then the level of output demanded by them will represent the optimal allocation of society's resources to water supply.

Other more popular types of equity concerns appear at odds with this cost allocation concept of equity in economic theory. It is quite difficult for many people to accept the idea that large volume peak uses such as lawn sprinkling should not be discriminated against. But the implication in this is that lawn sprinkling is a lower-valued use than other basic domestic water requirements. The peak rate structure sanctioned by economic theory simply puts this implied hypothesis to the test. It seems likely that peak period marginal cost rates would indeed produce significant reductions in lawn sprinkling. However, there are many other water uses for which the value is more difficult to judge. In these grey areas, the peak period marginal cost approach decentralizes the decision on valuation, thus producing greater efficiency in water use than could ever be attained through the other approaches. A central authority cannot possibly perform such a multitude of valuations without making many errors that individual users would never commit in determining their own desire to consume.

It is further argued though, that economically equitable cost allocation is inequitable in its effects on low income groups. Why should rich people be able to indulge in lawn sprinkling while poor families are forced to pay a summer premium for dishwater? There is no denying that this is undesirable. But the economist notes that water pricing policy is not necessarily the best place to solve problems of income distribution. Attempts to redistribute income through the price of water simply distort the price of

water, producing inefficiencies throughout the economy. In economic terms, it costs society a lot more to redistribute income in this manner than what it would cost to address the problem more directly through the tax system.

D. THE ROLE OF PRICING IN REGIONAL WATER SUPPLY PLANNING

1. The Basic Question

On the surface of it, the basic question regarding the role of pricing in water supply planning is: "Can pricing be used as a means of depressing the rate of demand growth to economize on capacity requirements?" The short answer to this question is yes; if you raise prices high enough, you will ultimately get the desired effect on demand. But this simple answer cannot be accepted as policy without examining further questions such as: "How high must prices be raised in order to achieve this effect; and, will it be worth it -- are high prices justified by the savings in capacity cost or will the cure be worse than the disease?"

To investigate these questions, it is appropriate to begin by a review of the relationships between the price charged on peak period consumption and demand growth; relationships evident from the theoretical analysis of Section C for the case of an individual utility. First and foremost, if price is set equal to marginal cost, then the quantity demanded will be just equal to the opportunity cost of the resources required to produce that quantity. This is an optimal situation at any given point in time and will also result in an optimal rate of demand growth over the long-term. If price is set below marginal cost (as in uniform average cost pricing), then the price signal to the consumer encourages over-consumption and the rate of demand growth will be faster and less efficient than that of marginal cost pricing. If price is set above marginal cost (as in rate strucures intended to induce water conservation), then the price signal sent to consumers will discourage consumption and produce a lower than optimal rate of demand growth. More elaborate discussion of these points can be developed with the aid of Exhibits II-9 and II-10.

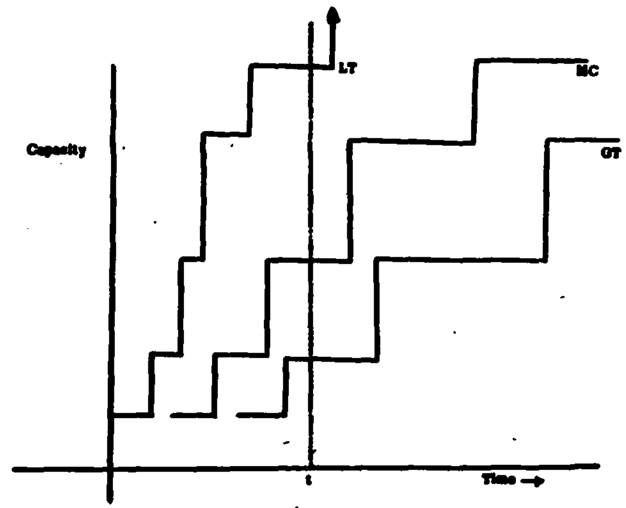


Exhibit II-9: EXPECTED RELATIONSHIP OF PRICING POLICY AND DEMAND GROWTH

Exhibit II-9 shows the time path of capacity additions in terms of the marginal cost of each capacity increment. It is shown that the rate of capacity growth and of cost increase is highest when rates are less than marginal cost (LT) and lowest when rates are greater than (GT) marginal cost. Marginal cost rates produce a growth pattern somewhere between the two (MC).

Taking a section through this diagram at a given point in time (as indicated by the dashed vertical line), it is possible to compare the economic efficiency of the three different approaches to pricing. This is accomplished in Exhibit II-10 which shows the marginal cost curve at time "t." Three different demand curves, representing the three pricing strategies are shown to intersect this curve at the capacity increments indicated by the section taken through Exhibit II-9.

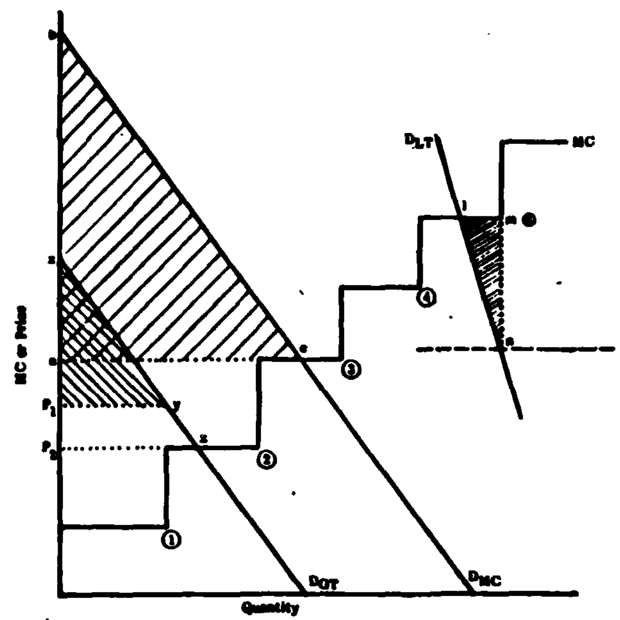


Exhibit II-10: EFFICIENCY ASPECTS OF DIFFERENT GROWTH RATES

In the case of prices less than marginal cost, the demand curve D_{LT} intersects the dashed horizontal line representing the lower price to produce an efficiency loss indicated by the triangle lmn. This triangle represents the portion of the resources required to provide the fifth increment of capacity that are not covered by revenue or consumers surplus. This loss of economic efficiency could be avoided by charging the marginal cost of the fifth capacity increment.

In the case of prices greater than marginal cost, the demand curve D_{GT} is shown to intersect the dashed line representing price P_1 resulting in a consumers surplus given by the area of triangle P_1xy. If instead the marginal cost of the second capacity increment were charged, the consumers surplus could be expanded to the size of the triangle P_2xz.

The demand curve D_{MC} intersects the marginal cost curve at the third capacity increment producing a consumers surplus equal to the triangle abc. This marginal cost price produces no losses in efficiency and it is not possible to adjust the price in any way that will expand the consumers surplus. In sum, if a marginal cost pricing approach is followed, then, at any point in time, the total "net benefit" to society (measured as consumers surplus less efficiency losses) will be maximized. If this is true for <u>any</u> point in time (any section through Exhibit II-9) it must then follow that the overall rate of capacity growth produced by this is similarly optimal.

Given this theoretical background, it seems a simple matter to conclude that the answer to the basic question posed in this chapter is: "Yes, price can be used to depress demand to lower levels and slow the rate of capacity growth; and, yes, this is justified if price is set equal to marginal cost." Surprisingly, this theoretical conclusion was not confirmed by the empirical findings of this study. The relationships shown in Exhibit II-9 were found to be very different from the actual situation. Remarkably, the marginal cost rates were lower than both conservation-oriented rates and average cost rates, producing a faster rate of capacity growth. This situation is depicted in Exhibit II-11.

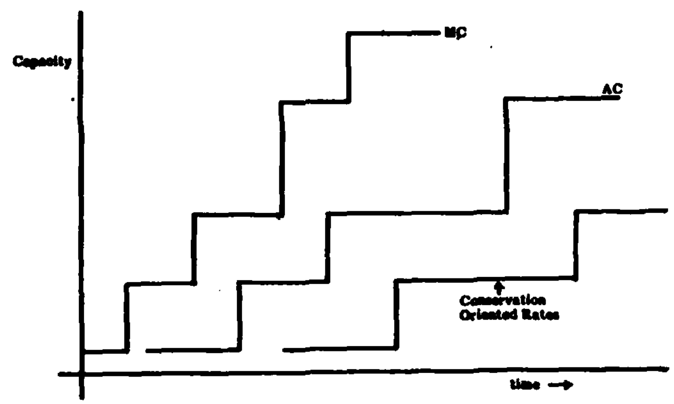


Exhibit II-11: ACTUAL RELATIONSHIPS OF PRICING POLICIES AND DEMAND GROWTH

The conservation oriented rate structures employed by the Washington Suburban Sanitary Commission (WSSC) and other utilities in the region were found to result in high volume users being charged very high rates for their peak period consumption; rates that were above marginal cost, as suspected. However, the peak period charges for the volume used by an average household were found to be roughly equivalent to average cost. Therefore, the rate of capacity expansion associated with these conservation oriented rate structures could only be expected to be slightly below that associated with average cost pricing.

A more important empirical finding was that the estimated value for the peak period marginal cost was below the average cost. This result stems from several factors:

- New developments in "supply management," explained below, greatly reduced the need for and cost of new capacity.
- Water and sewer utility service entails a very high proportion of "fixed costs" which are included in the average cost rate but are not counted as part of the marginal cost rate.
- Water and sewer consumption are both measured by the same meter for billing purposes. This has the unfortunate effect of causing the consumer to perceive a single price for two different services. Further distortion of this price signal results from the fact that sewer service is generally the more expensive, and that the peak capacity requirement for sewer service does not occur in the summer.

The consequence of these findings is that the peak period marginal cost rate would be less than the rate currently charged on peak consumption by most area utilities. This means that a switch to marginal cost peak period pricing would actually produce accelerated capacity growth, as indicated in Exhibit II-11.

From the picture presented in Exhibit II-11, it seems that the answer to the basic question regarding the usefulness of price as a means of controlling demand growth should be revised as follows: "No, marginal cost prices are not high enough to depress demand; and, prices higher than marginal cost, though perhaps effective, are not justified in terms of economic efficiency."

In another recent (1978) study of water pricing by utilities in the Washington, D.C. area (7), Philip H. Carver also found that the appropriate summer period marginal cost rate was below the rate currently charged. Carver's results showed much less of a discrepancy than that shown in the empirical results presented herein (Chapter III). His cost data did not reflect, however, the newly discovered benefits of "supply management." The insufficiency of his marginal cost rate can be attributed more to the other factors listed earlier pertaining to fixed costs and to the treatment of sewer costs.

Other case studies conducted by Carver and Boland (6) are also worthy of note. In Atlanta, Georgia it was again found that the summer marginal water rate failed to equal the current price being charged. In Tucson, Arizona, however, it was found that the high cost of new water supplies made marginal cost peak period pricing a viable concept for demand reduction.

"Supply management" is a term used to describe strategies for maximizing the output of water supply capacity. It has recently been found that by careful synchronized timing of releases from existing reservoirs on the Potomac, Patuxent, and Occoquan the extent of demand served by existing facilities can be greatly expanded. One recent analysis showed, for a given level of demand, that only one small new reservoir would be needed between now and the year 2030. This new development has the effect of greatly reducing the cost of additional increments of capacity -- the marginal cost.

Facing this new reality, the economist is tempted to say that the answer to the basic question posed in this section should be: "Existing rates are too high. They should be reduced to the level of marginal cost and consumption should be expanded. Because water is no longer as expensive, it is economically efficient to make greater use of it." This answer is very unsatisfying to a large number of people involved in water resources planning within the region. After many years of worrying over the narrow adequacy of supplies, it is not easy to accept this conclusion.

An important perspective on this issue is that much of the difficulty in securing approval for development of new supplies has stemmed from strongly held views by numerous segments of the public regarding:

- the direct environmental impacts of new water supply development projects;

- the indirect effects of water supply expansion on the extent of environmental damage caused by urban/surburban growth and development (not the least of which is the very closely related impact of expanded waste water discharge.); and,

- the inequity that results from residents of upstream and downstream areas bearing the physical impacts of projects that benefit the metropolitan area.

These items are important because they are, in effect, additional costs that society must bear in the development of water supplies. Water resource planners and interested public groups would be very skeptical if the economist concluded that current prices should be reduced to the level of the calculated marginal cost because these more "intangible" types of costs are, for the most part, not included in the marginal costs calculated by Carver or in Chapter III of this report.

From a theoretical standpoint, the marginal cost should represent the total cost to society -- the full social costs; both tangible and intangible. Economists have developed analytical methods designed to estimate the more intangible types of costs. These estimates involve substantial research, however, and such studies have not been undertaken for the case of the Washington Metropolitan Area water supply problem. Estimates produced by such methods are, in any event, very controversial and frequently leave the issue at least partially unresolved. Ultimately, a value judgement must be made.

From this vantage point, the answer to the basic question may be once again revised, as follows: "It is justifiable to add an extra premium to the calculated marginal cost price to account for intangible costs. However, the effect of the resulting rate on demand cannot be forecast because it is a function of the amount of the premium." In other words, "Price may be able to reduce demand growth if the public feels that the intangible costs are high enough to justify the extra premium. The level of reduction provided depends on the strength of that feeling."

Carver provided a glimpse of how such an approach might work. He investigated the question of the maximum extent to which increased prices, under different rate structures, could be used to reduce demand. His analysis was structured to calculate and compare the losses in consumers surplus that result from price increases under the different rate structures. The results of this empirical model showed that the peak period marginal cost rate design had the smallest losses of all alternatives. Alternatives evaluated included the current Washington Suburban Sanitary Commission increasing block structure, the unique Fairfax County Water Authority rate structure, and uniform rates.

In undertaking this analysis, Carver was not specifically addressing the question of intangible costs (though it is implied), but it is a useful context in which to offer a theoretical rationale for his results. If the originally calculated peak period marginal cost price was too low by the amount of the intangible costs, then adding this amount changes none of the optimal efficiency characteristics of the peak period marginal cost rate structure. With the full social cost accounted for, the new marginal cost price will produce an optimal set of outcomes. On the other hand, the same premium for intangible costs added to the other rate structures would tend to exacerbate the economic inefficiencies inherent in them.

Some practical problems are associated with the concept of charging customers for intangible costs. Most utilities operate under a "revenue constraint" that specifies that revenues should not exceed their tangible accounting-type costs. The premium for intangible costs would create a surplus. However, Carver shows that there are several ways of alleviating this type of problem without sacrificing the integrity of the desired rate structure. Nonetheless it is a major stumbling block to the implementation of such a pricing scheme and would require quite extensive preliminary research.

Finally, conclusions regarding the basic question addressed in this section can be summarized as follows:

- If only the tangible costs are considered, the calculated marginal cost peak period price cannot be effectively used to reduce demand growth. Current conservation oriented rate structures charging rates above marginal cost are not justified on the basis of tangible costs. The impetus for conservation supporting these rate designs implies some type of additional valuation attributable to intangible costs.

- If intangible costs are included, then resulting peak period marginal cost prices may be sufficient to induce reductions in demand growth. The economist can neither prescribe the level of intangible cost nor predict the extent of demand reduction. The economist can say with certainty, however, that a marginal cost peak period rate structure should be used to achieve the optimal result.

2. The Underlying Question

Carver uses an interesting diagram (replicated in Exhibit II-12) to convey the results of his analysis. In investigating the maximum extent to which price may be used to control demand under different rate structures, he organizes the problem as a three-way trade-off between the cost of new supply, the cost of shortage, and the loss of consumers surplus produced by pricing policy. This three-way trade-off is represented on the same diagram by showing the cost of new supply and the cost of shortage in terms of the losses in consumers surplus that are associated with them.

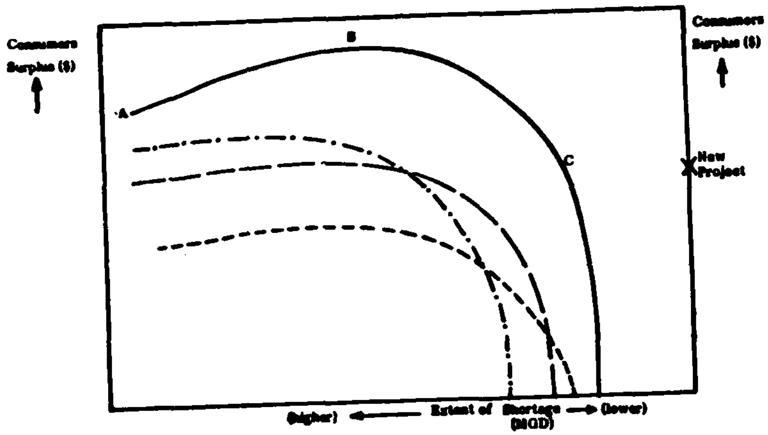


Exhibit II-12: THREE-WAY TRADE-OFF IN WATER PRICING AND CAPACITY PLANNING

In Exhibit II-12, the vertical axis measures the value of the consumers surplus, increasing towards the top of the box. The horizontal axis measures the extent of shortage which decreases towards the right. In the case where rates are raised up to the level of marginal cost, consumers surplus will be increased while the level of expected shortage is decreased. This produces an upward sloping curve similar to segment AB in Exhibit II-12. If rates are raised excessively above marginal cost, a point (such as point C) will eventually be reached at which the loss of consumers surplus due to overpricing exceeds the cost imposed by the next increment of shortage. As a result there is always a gap at the right side of the diagram indicating that it is never worthwile tc try to avoid every gallon of shortfall. This would entail pricing high enough to suppress demand during even the most extreme drought events.

The alternate means of averting shortage is, of course, to build new supply projects. Such a project is indicated in the diagram by the X-mark on the right-hand side of the box. The distance of the X-mark from the top of the box represents the loss of consumers surplus that results from the higher cost of the new project. However, the presence of the X-mark on the extreme right-hand side of the diagram reflects the compensating fact that the gap in supply has been closed and shortage cost reduced to zero.

This diagram highlights two important aspects of the water supply planning problem:

- The determination of capacity requirements is a "stochastic" problem, heavily dependent on probabalistic climatic events that determine the risk of shortage.

- The three way trade-off involved is essentially a benefit/cost type of problem.

The benefit/cost aspect is deserving of special note. It is recalled from the discussion in Section C that the area under the economist's demand curve represents the total value placed on a good. The consumers surplus is the area under the demand curve but above the cost curve; it is the extent to which consumers value a good more than the cost of the resources required to produce it. When price is set equal to the resource cost, consumers enjoy that extra value for free -- a surplus. The consumers surplus is therefore widely used as an estimate of the "net benefits" derived from the consumption of a good (benefits of consumption minus resource costs).

In benefit/cost analysis, the objective is to determine which alternative course of action produces the *maximum net benefits* (or, what is the same thing, the maximum ratio of benefits to costs). The diagram in Exhibit II-12 captures the essential benefit/cost comparisons entailed in attempting to maximize net benefits in water supply capacity planning. The three-way trade-off is focused around the following questions:

- Does the loss of consumers surplus from excessive pricing exceed the loss of consumers surplus due to the risk of shortage?
- Does the loss of consumers surplus from excessive pricing exceed the loss of consumers surplus due to construction of a new higher cost facility?
- At a given price, does the loss of consumers surplus due to the risk of shortage exceed that from the construction of a new higher cost facility?

These three questions capture the essence of the true role of pricing in water supply planning; pricing policy determines the amount of consumers surplus that is made available by these trade-offs. The perspective provided by this formulation of the problem is that the basic question posed in the previous section is too superficial. It is not enough to ask, "Can pricing be used to reduce demand growth?" The inescapable underlying question that must be addressed is, "What schedule of water supply development will provide the maximum net benefits?"

In Section C, it was theoretically shown that marginal cost peak period pricing produces greater consumers surplus than any alternative rate design. Carver found the same result. This is indicated in Exhibit II-12 by the position of the solid-line curve, representing a peak period rate, which lies above all the dashed-line curves representing alternate rate structures. The implication of these findings is that the peak period rate design will provide greater net benefits than any alternative and thus promote optimal scheduling of water resource development in a benefit/cost sense. However, these analyses have been developed only for the case of an individual utility. This second part of Section D looks at the underlying benefit/cost question from the standpoint of regional water supply planning. Additional complication enters in at the regional level because several utilities are involved. The total amount of consumers surplus available to the region will be the sum of the surpluses of the individual utilities. Finding the

maximum value of this sum adds an extra dimension of complexity to Carver's three-way trade-off. The ensuing analyses show that marginal cost peak period pricing is also uniquely capable of ensuring maximum net benefits at this more complicated regional level.

a. Benefit/Cost Context of The Corps Draft Progress Report

As noted in several places above, this study was conceived on the presumption that the addition of new increments of water supply capacity was an increasingly expensive proposition. This notion is regarded as the conventional wisdom in capacity planning for major urban areas where cheap and easily accessible water sources have already been developed. The interim results of the Corps of Engineers planning for the Washington Metropolitan Area as reported in their August 1979 Draft Progress Report (4) were characteristic of this view.

The development of supply scenarios in the Draft Progress Report was based on an initial set of assumptions which restrict the scope of benefit/cost analysis to something less than the all-encompassing benefit/cost framework specified by Carver (Exhibit II-12). The Corps of Engineers and the utility managers in the region elected to study supply alternatives designed to meet the most extreme 7-day shortage that would occur in one out of every one-hundred years. In selecting this design criterion, they implicitly made one of the three benefit/cost trade-offs entailed in water supply planning; fixing the answer to the shortage cost dimension of the problem.

As summarized in the earlier discussion, Carver defined a three-way trade-off in benefit/cost analysis of water supply planning as follows:

- shortage cost vs. cost of new supply
- shortage cost vs. consumers surplus produced by pricing policy
- cost of new supply vs. consumers surplus produced by pricing policy

The Draft Progress Report replaces the shortage cost dimension with an assumption; thus reducing the benefit cost question to a two-way trade-off between the consumers surplus losses of pricing policy and those associated with the cost of new supply projects. Economists would probably prefer to insert some more explicit benefit/cost analysis into this step but, considering that quantifying shortage costs involves much technical understanding and experienced judgement, the educated consensus of these officials is probably as good an assessment of these benefits and costs as could be produced through any further research on the subject.

As a result of eliminating the shortage cost dimension of the problem, the benefit/cost context of the Draft Progress Report is limited to the one remaining set of trade-offs; those between cost of the new supply and the consumers surplus produced by pricing policy. Within this context, the best that can be hoped for is to maximize the excess of benefits over costs <u>for a given level of shortage</u>. The Draft Progress Report pursues this objective by determining which water supply development scenarios will minimize the cost of new supply. This approach, ignores any possible trade-offs between the consumers surplus produced by pricing policy and by the cost of new supply.

Using this approach, the Draft Progress Report concludes that scenarios involving regional cooperation are the most economical. The rationale for this conclusion is not necessarily justifiable in terms of benefits and costs, however, precisely because the role of pricing policy was ignored. In the next subsection, the theoretical merits of cooperative regional plans are compared to those of scenarios for independent local water supply development. Cooperative regional plans are shown to have significant theoretical advantages, but these advantages are also shown to be contingent upon certain conditions that are not met by the analysis in the *Draft Progress Report*.

b. Theoretical Comparison of Regional Cooperation Vs. Local Action

As a starting point, the case of independent, non-cooperative, local action is illustrated in Exhibit II-13.

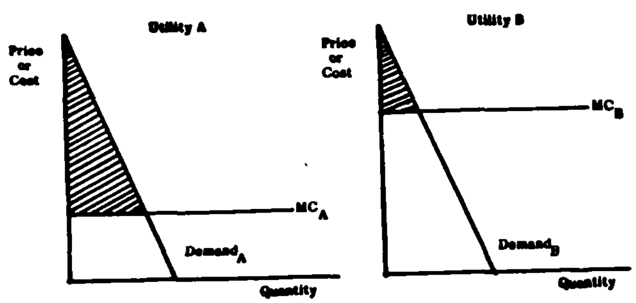


Exhibit II-13: EFFICIENCY CHARACTERISTICS OF INDEPENDENT LOCAL ACTION

In this case where utilities A and B develop their own separate water sources, it is not unlikely that the cost of the next increment of capacity will be greater for one utility than it is for the other. It is assumed that this results simply from the geographic situation of the two utilities relative to available new water sources; it is not feasible for them to share the same source or to build a pipeline between them. If both utilities charge a peak period price equal to their marginal cost, the resulting consumers surpluses available to their customers are shown in Exhibit II-13.

The obvious conclusion from this diagram is that customers in one jurisdiction enjoy more consumers surplus than their counterparts in the other jurisdiction. In the case where the two utilities are widely separated by geography and do not both draw upon the same regional water resources, the apparent inequity in this distribution of consumers surplus is not inefficient from the standpoint of economic theory. It simply means that water is more expensive in one area than it is in the other, and the cost difference is less than the cost of a pipeline between them.

Charging marginal cost peak period prices in both areas will result in the optimal allocation of water to various uses in the local economy in each area. These allocations will be different and what looks like wasteful consumption in one area may be an economically justifiable use of water in the other. The efficiency of both allocations will nonetheless be optimal.

In the case where both utilities draw upon the same regional water resources, even if they are situated on distant extremities of the watershed, the optimally efficient allocation of water may require regional cooperation. Local independent action cannot be efficient <u>if there is a feasible opportunity to share</u> the same water resource development projects. This is so because the efficiency of marginal cost pricing is based on the fact that the marginal cost reflects the "scarcity" of the resource. If the resource is more scarce, a higher value must be placed on it to assure efficient use of it. If two utilities wish to draw on the same limited pool of a resource, the allocation between them can only be efficient if they both pay the same marginal cost price for that resource. If the utilities instead build separate projects at differing costs as in Exhibit II-13, then even if they charge prices equal to the marginal cost curves they face, the resulting allocation of water will not be optimally efficient for the region because the regional scarcity of water can only be represented by a single price -- the regional marginal cost.

Exhibit II-14 illustrates the inefficiency of independent development of supplies when the water resources being developed are in fact regional in character (i.e., capable of being shared). In this diagram the apparent inequity of Exhibit II-13 is shown to also produce losses in economic efficiency.

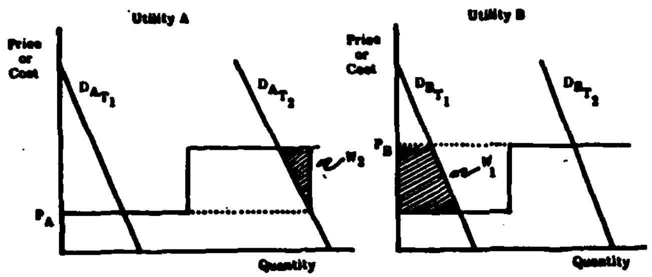


Exhibit II-14: EFFICIENCY CHARACTERISTICS OF INDEPENDENT LOCAL ACTION WHEN REGIONAL COOPERATION IS FEASIBLE

The step-shaped curves in Exhibit II-14 represent the regional marginal cost curve. If the utilities act independently as before, then Utility A would charge Price P_A while utility B would charge the higher price P_B.

At time T_1, assume that the regional marginal cost is equal to P_A. Utility A is therefore pricing at the level of the correct regional marginal cost. Utility B, however, is pricing above the regional marginal cost. Utility B customers are deprived of consumption equal to the value of the lost consumers surplus -- area W_1.

At time T_2, assume that the regional marginal cost is equal to P_B. Utility B is pricing at the optimal level while utility A is pricing below regional marginal cost. Utility A customers are therefore over-consuming and producing an efficiency loss equivalent to the area W_2.

It is concluded that cooperation between utilities produces greater overall net benefits when it is feasible to share the resources regionally. It is important to note, however, that the efficiency of regional cooperation that has been demonstrated in the foregoing analysis is contingent upon two key assumptions:

(1) The participating utilities must have a peak period rate equal to the marginal cost.

(2) The allocation of regional supply costs to the utilities must be such that the marginal cost curves facing them are exactly alike.

Deviations from both of these conditions were present in the scenarios presented in the Draft Progress Report. The following two subsections further elaborate on the effects of such errors in pricing and in cost allocation.

c. The Effect of Errors in Pricing

Exhibit II-15 illustrates efficiency losses that result from improper pricing by utilities participating in a regional program. Areas W_1 and W_2 represent the efficiency losses produced by under-pricing on the part of utility A. Areas W_3 and W_4 represent losses of consumers surplus produced in the case where utility B pursues a policy of over-pricing. If any one of the participating utilities deviates from optimal marginal cost pricing, the total net benefits for the region cannot be maximized.

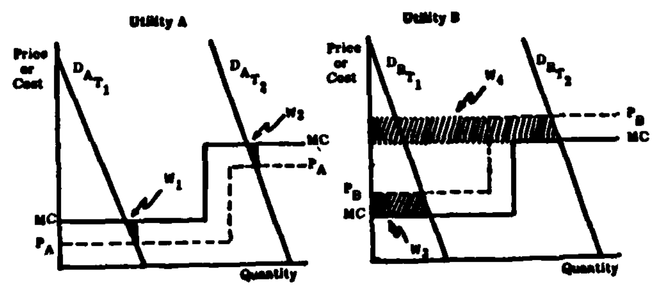


Exhibit II-15: EFFICIENCY ASPECTS OF PARTICIPATION IN A REGIONAL PROGRAM

Deviation from peak period marginal cost pricing generates inequities as well as inefficiency. This comes about because the peak period price is a very important determinant of the rate at which capacity must be expanded. If one of the participating utilities is charging a lower peak period price than the others, then it is contributing more to the need for new capacity; shifting the entire regional marginal cost curve upwards and to the left. The other utilities participating in a regional program have to endure more rapidly increasing costs while customers of the under-priced utility enjoy some extra consumers surplus.

This type of inequity can arise in a regional plan in two ways:

- A utility such as Utility A in Exhibit II-15 may be under-pricing due to the use of a rate structure that charges less than the marginal cost during the peak period. Other utilities charging the proper peak period marginal cost price would view this as unfair.

- A utility such as utility B in Exhibit II-15 may be over-pricing due to the use of a conservation oriented rate structure based on the belief that the calculated marginal cost is too low. In this case, utility B might feel cheated and believe that the other utilities are under-pricing.

If either situation is perceived to exist in regional arrangements, it may form a barrier to institutional cooperation. However, this <u>inequity between utilities</u> is not the underlying cause of the economic inefficiencies illustrated in Exhibit II-15. These inefficiencies are actually brought about by <u>inequity between peak period water users</u>. Economically efficient results are produced only when the rate structures of all participating utilities correctly charge the marginal cost of peak capacity to peak users. This efficiency criterion is, in effect, a type of equity criterion: each user should pay the full cost of his own consumption.

Peak period marginal cost pricing is a rate design that is uniquely capable of allocating capacity costs to peak users in the most equitable fashion. At the regional level, the only way that this same equitable treatment can be obtained is if all participating utilities employ the same peak period marginal cost rate structure. At present, there are no peak period marginal cost rate structures in use in the region. Further, the rate structures being used are all different from each other. This situation automatically

produced inequities and inefficiencies of the type discussed above in all regional scenarios presented in the Draft Progress Report.

d. The Effect of Errors in Cost Allocation

The criterion of equity between peak users which is implicit in the peak period marginal cost rate structure is an important aspect of the role of pricing in regional water supply planning. However, optimal results cannot be assured by simply encouraging all utilities to adopt the same peak period rate structure. This ideal rate structure allocates the utility's capacity costs to users in an efficient manner, but, in the context of a regional plan, the efficiency of the allocation made by the utility's rate structure is contingent upon a prior allocation that determines the utility's share of the total regional capacity cost. The allocation of capacity costs between utilities must be such that they are all facing the same marginal cost curve for common facilities. The regional scenarios developed in the Draft Progress Report involved some fundamental problems that complicated this objective.

The development of regional scenarios requires a set of criteria for selecting the next water supply projects to be built to meet regional demand. The economist would favor a simple rule of taking the least expensive project first, the next expensive second, and so on. That principle was followed in general in the Draft Progress Report but became compromised by constraints of geography and the associated design of regional cost-sharing arrangements.

The Draft Progress Report presented scenarios showing various combinations of cooperative regional approaches and independent local actions. In local action scenarios, the geographic proximity of source development projects to water utilities determined which new projects were assigned to their demands. Costs were then allocated according to these assignments. This procedure produced inequities in the degree to which the different utilities share in the least cost projects for the simple reason that new projects in some areas are more expensive than those in others. Another factor producing inequities was the fact that projects have varying capacities; thus one utility may have faced the need to build two new small facilities during the planning period while another utility could get by with a single larger facility.

In scenarios for cooperative regional or subregional action, inequities in cost sharing between utilities resulted from these same constraints of geography and uneven capacity as well as from the initial allocation of regional water supplies. In the Draft Progress Report's scenario development process, presently available supplies were initially allocated among utilities to determine the extent of their participation in new projects. This initial allocation step was partially based on geographic constraints: the Maryland suburbs were constrained to make full use of Patuxent sources before sharing in the Potomac and Fairfax County was similarly constrained to make full use of the Occoquan.

The basis for the initial allocation of available water supplies in the Draft Progress Report scenarios was the Potomac Low Flow Allocation Agreement (LFAA). This agreement was originally intended as a device to distribute the total water available in the region (including Occoquan and Patuxent sources) on an equitable basis during extreme drought events. The formula used to accomplish this distributes the total regional supply among utilities in proportion to their winter season -- or offpeak season -- demands.

The LFAA water allocation formula has some conceptual appeal from the standpoint of economics. By basing the peak period allocation on the off-peak level of demand, it creates an incentive for the utilities to reduce their peak demands. However, geographic constraints affecting the resulting allocation of water between utilities produced unequal participation in the various projects. Since these projects each had different costs and capacities, unequal cost sharing between utilities was the ultimate result.

Any inequities resulting from these initial allocations and project sharing arrangements were further distorted by the deduction of "environmental flow-by" from Potomac supplies. Environmental flow-by is a minimum amount of water that must remain in the Potomac to preserve water quality in both the freshwater and estuarine portions of the river. If water utilities were to suck the river dry during extreme drought conditions, the environmental impacts of this action could be very severe. This is an "environmental externality" associated with water use; it is an extra cost (an intangible environmental cost) that would not normally be included in the market price charged to water users.

In this case, however, the environmental externality has been "internalized" by the decision of the regional authorities in the LFAA to allow some minimum quantity of water to "flow-by." In economic theory, it is considered efficient to internalize externalities by adding a sufficient premium to the market price so that users pay the full social cost of their consumption. The solution employed here was to make a sort of "payment-in-kind" for the externality by leaving flow-by in the river. The users end up paying a higher price that reflects the internalized externality because the amount of flow-by deducted from available supplies must be made up by the construction of an equivalent amount of new capacity.

While this treatment of the flow-by externality appears efficient, it was nonetheless inequitable due to the initial allocation of the available supplies. Because this initial allocation was based in part on geographically constrained initial shares of non-Potomac sources, more of the cost of compensating for the flow-by deduction was allocated to some users than to others. In fact, the environmental damage to be avoided by providing flow-by was caused by all peak users in the region and they should all share equally in the cost.

The net effect of these imperfections in the allocation of water supply capacity, and of its costs is illustrated in Exhibit II-16. This diagram shows resulting marginal cost curves for the three major Potomac-dependent water service areas that are very different from one another. These three curves are taken from one of the scenarios developed in the Draft Progress Report and are typical of the Draft Progress Report scenarios. They demonstrate the distortion caused by the various geographic, project capacity, low flow allocation, and environmental considerations that entered into the water and cost allocations.

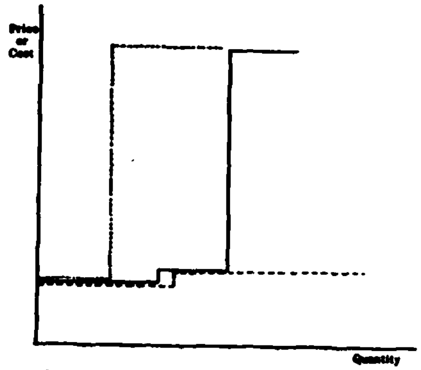


Exhibit II-16: DIFFERENT MARGINAL COST CURVES FROM DRAFT PROGRESS REPORT

The ideal solution to this dilemma would be to find some way to remove the constraints affecting the allocations of water and costs between utilities. It would have to somehow be possible to build one new facility at a time in a central location, available to peak users in all utility service areas. This would eliminate geographic and capacity constraints entailed in allocating new project costs. It would also be necessary to pool all regional water resources together to even-out differences between the location of the water and the demand to be served. This would allow all regional facilities to be used to satisfy the total demands of the combined service areas. The pooling together of regional supplies would also produce an equitable allocation of the cost of providing environmental flow-by.

Such an ideal solution has happened to come along in the form of "supply management." The optimization and joint use principles of supply management fit the above prescription perfectly and, as discussed in the next subsection, provide new opportunities to maximize regional net benefits. This opportunity is further enhanced by recently proposed revisions to the Low Flow Allocation Agreement which would correct the flaws in the cost-sharing formulas applied in the Draft Progress Report.

e. Maximizing Regional Net Benefits in the Context of Supply Management

As described earlier, "supply management" refers to a plan for synchronizing the releases from existing storage facilities in the region in a manner which will expand the total capacity that is available during peak periods. Results of preliminary studies of the concept indicate that it could significantly expand supplies in the Washington Metropolitan Area.

By its very nature, supply management removes many of the obstacles to efficient cost allocation between utilities participating in a regional plan. Since supply management uses all of the facilities in a region simultaneously, the role of geographic proximity in determining water and cost allocations may be eliminated. In construction of new facilities, the additional capacity can be shared by all participants in the plan, regardless of the location or the capacity selected.

On the surface, supply management appears to provide solutions to all of the cost allocation problems that previously made it difficult to develop regional scenarios having optimal efficiency characteristics. It is not correct to conclude, however, that net benefits will automatically be maximized under supply management. Supply management makes it possible to devise regional cost sharing arrangements that produce the same marginal cost curve for each participating utility. But in order to assure maximum net benefits it is also necessary to satisfy the condition that each peak user must face the same peak period marginal cost price.

The empirical portion of this study presented in Chapter III, develops estimates of peak period marginal cost prices that would face the utilities in the Washington Metropolitan Area under a regional plan employing supply management. The results show that the cost of new capacity is so greatly reduced by supply management that the marginal cost prices are actually lower than the prices currently being charged. It would seem from these results that pricing simply does not work in this case and therefore has no further role in regional water supply planning.

There are, however, several factors which may cause the estimates made in this study to change. Among these are the following:

- The amount of demand reduction due to conservation may be less than expected.
- The amount of flow-by required to sustain environmental quality may be greater than expected.
- Various factors affecting cost forecasts could change.
- The actual costs faced by utilities may be calculated on a different basis from those forecast here.
- An extra allowance for intangible social costs may be warranted for items not included in study estimates.

Sensitivity analyses show that it would take a lot of these things to change study results significantly. Even at 600 MGD flow-by, the marginal cost peak rate is still below

current rates for most utilities. These sensitivity results seem to confirm that, at present, marginal cost peak period pricing cannot effectively reduce demand, though some uncertainties remain over the longer-term.

While marginal cost peak period pricing does not appear to have a near-term payoff due to the economies of supply management, the opportunities for proper cost allocation made possible by supply management may have an important role to play in long-term water supply planning. In developing cost allocations in the empirical portion of this study a hypothetical institutional arrangement was envisioned which would produce a proper allocation of the costs of new capacity to peak users in all utility service areas. The idea called for the establishment of a single regional authority to run supply management operations and build new increments of capacity as needed. In a very recent development, revisions to the *Low Flow Allocation Agreement* have been proposed which incorporate a cost-sharing formula that has the same optimally efficient characteristics.

The newly proposed LFAA cost-sharing formula would distribute the costs of new supply facilities among participating utilities according to their share of the growth in peak period demand. This formula has a number of interesting features including the following:

- In the near-term, supply management has so greatly reduced the cost of new capacity that this cost allocation formula may not have a significant impact on utility pricing practices.

- Over the longer-term, say, the year 2000, errors in earlier forecasts or other factors (e.g. accounting for externalities) may cause new capacity to once again be viewed as an expensive proposition. As costs rise, the LFAA formula will give utilities in the region a much stronger incentive to adjust their rate structures in an effort to reduce peak consumption. Ultimately, marginal cost peak period pricing may emerge, but the utilities are not constrained to employ this approach.

- As costs change, this regional cost allocation mechanism will automatically produce these adjustments in the way utilities set rates for peak consumption. It will not be necessary to conduct further studies to

determine the point at which marginal cost peak period pricing becomes feasible or desirable; instead, it will happen automatically.

- The structure of the incentives set up by this mechanism will be exactly the same and will reinforce that produced by the LFAA water allocation formula. They both provide utilities with an incentive to reduce their peak demands.

In summary, supply management has provided not only great economies in water production but also great opportunities to develop optimally efficient mechanisms for regional cooperation. The role of pricing is central to the operation of these mechanisms. Though optimal pricing practices will not produce immediately beneficial results, the cost allocation principles supporting pricing theory are key to realizing the maximum net benefits from supply management over the longer-term. Proposed LFAA revisions can help assure an optimal outcome.

III. EMPIRICAL APPLICATION OF MARGINAL COST PEAK PERIOD PRICING

A. OVERVIEW

The preceding chapter examines the theoretical role of pricing in water supply planning based on the assumption that it is possible to develop a theoretically optimal rate structure. The objective of the portion of the study effort reported in this chapter was to actually apply the theory in developing marginal cost peak period rates from empirical data to see if the theory is practical. This entailed the following analytical steps:

(1) Collect cost data (water and sewer).
(2) Project costs into the future.
(3) Ascertain the existing rate structure formulas that are used to convert costs into rates.
(4) Project future rates under existing rate structures.
(5) Develop formulas to convert costs into marginal cost peak period rates.
(6) Project future rates under marginal cost peak period pricing.
(7) Compare future rates under existing and marginal cost rate structures.
(8) Find the best available estimates of elasticity to determine the effect of a change to marginal cost peak period rates on the future demand for water.

Because water and sewer services are most often billed together, it was necessary to perform these analytical steps for all water utilities and their associated sewer utilities in the region. Results of the empirical analyses are summarized in this overview section of Chapter III. Subsequent sections describe analytical methods employed in each of the various steps.

1. Consideration of Environmental Flow-By

Before the results can be presented, it is necessary to explain certain analytical complications resulting from the treatment of "environmental flow-by" in the empirical work. As defined in Chapter II, "environmental flow-by" is a minimum amount of water that is allowed to "flow-by" the water intakes in order to preserve water quality in the

Potomac. The result of making this allowance for flow-by is that there is less water available to start with and more new facilities are needed to meet regional demands.

Complications stemmed from the fact that the exact amount of flow-by necessary to preserve water quality was not known at the outset of this study. The appropriate amount was thought to be somewhere in a wide range between 100 and 1000 million-gallons-per-day (MGD). To cope with this uncertainty several scenarios of water supply projects were evaluated representing flow-by levels of zero MGD, 100 MGD, 300 MGD, and 500 MGD. It turns out that the 100 MGD level is now regarded as the target amount but results are presented at all levels because the analysis of different levels of flow-by can, in effect, be regarded as a sensitivity analysis for other estimates and assumptions used in the empirical work.

2. Existing Rate Structures

In the conventional approaches to rate setting and cost accounting which characterize the utilities in the Washington Metropolitan Area, the basic rule of thumb is that rates should be set such that revenues and costs are equivalent. The simplest way to achieve this is to determine the rate by dividing the total cost by the gallons sold. This produces a "uniform average cost" price (discussed in Chapter II). This rate structure has the advantage that it requires neither sophisticated accounting of costs nor complicated mathematics in the computation of rates.

There are many rate structures which seem outwardly more complicated than uniform average cost pricing but nonetheless amount to the same thing. The usual restriction that total revenues and total costs be equated often results in a situation in which the average consumer faces approximately an average cost price. This was found to be the case in the Washington Metropolitan Area. Exhibit III-1 presents a plot of price vs. average cost for the utilities drawing from the Potomac. The cluster of the points about the 45° line in this diagram illustrates this finding.

Based on these results, the forecasts of future costs for each utility were converted into forecasts of future water rates by simply computing the average cost. The resulting projections of average costs for the Potomac-dependent utilities are summarized in Exhibit III-2.

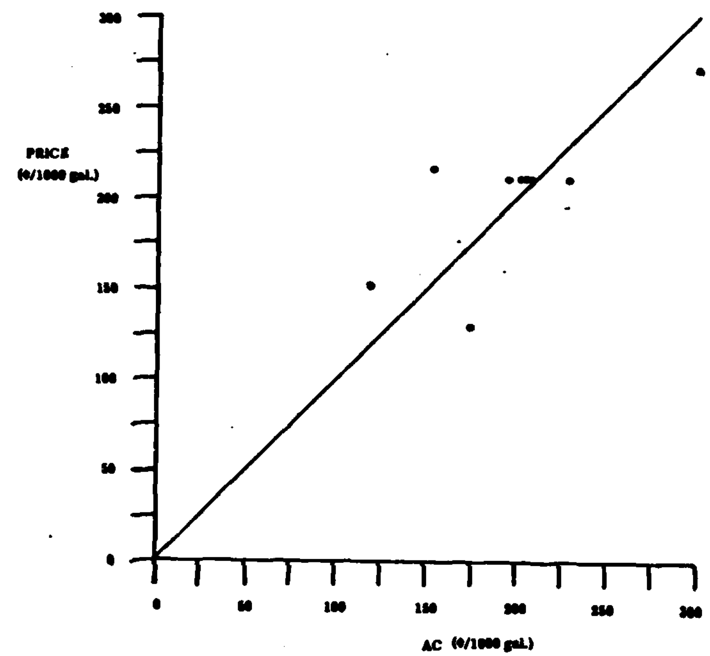


Exhibit III-1: PRESENT PRICE VS. AVERAGE COST

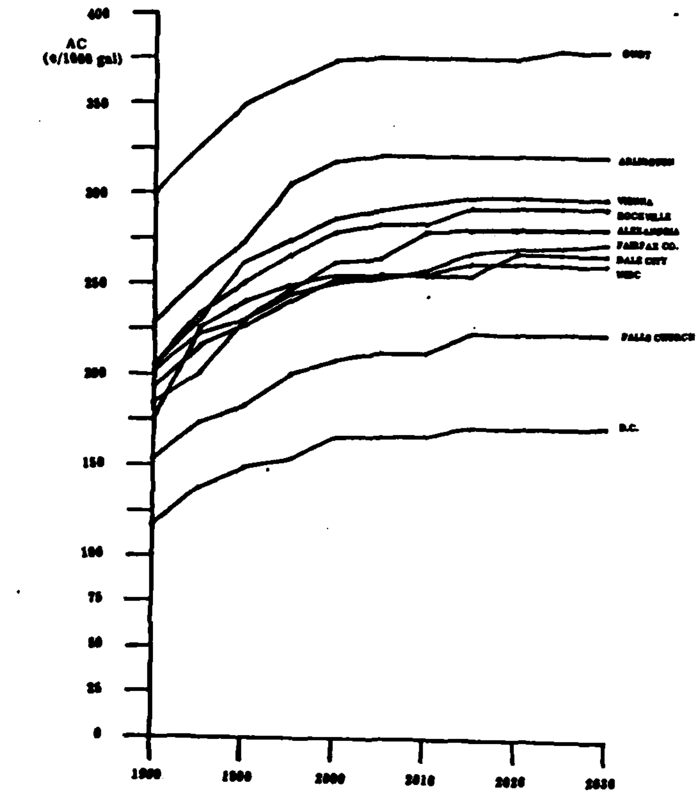


Exhibit III-2: AVERAGE COST PROJECTIONS AT ZERO FLOW-BY

The gradual upward trend shown in the cost projections of Exhibit III-2 is partially due to inflationary effects. This and other cost forecasts are presented in constant 1980 dollars. The rate of cost escalation shown may impress some observers as being too low, especially those aware of the high cost of new facilities and expansions of capacity. But herein lies the central flaw of average cost pricing. The new expensive facilities are "averaged-in" with older facilities built many years ago. Thus, the average cost curve does not rise as dramatically as some might suspect it would.

Because the high cost of new capacity is averaged with lower cost older capacity in computing present rates, it is not evident from the price signal that some of this new capacity would not be needed were it not for peak period demand. Average cost pricing spreads the extra cost of peak capacity equally over all consumers; moderate water users subsidize heavy peak users. This is the problem that economically efficient pricing is designed to solve. Peak users should bear a larger share of new capacity costs because new capacity would not be necessary if it were not for peak demand; it would be "avoidable."

3. Avoidable Costs and the Development of A Marginal Cost Peak Period Rate Structure

As discussed in detail in Chapter II, marginal cost peak period pricing is designed to make sure that each consumer pays the full cost of his own consumption -- no more, and no less. An inverse way to state this is that each customer pays for the costs that would have been avoided if his consumption had not taken place. It is therefore appropriate to refer to this approach to pricing as "avoidable cost pricing." This is a useful phrase to keep in mind to help in defining cost categories needed to empirically apply this approach to pricing.

It is not so easy to apply the economists' pricing strategies empirically because accounting-type cost data do not provide a straightforward distinction of "avoidable costs." Three categories of cost data are required:

- fixed costs (fixed in both the short-run and the long-run)
- short-run marginal costs (vary with consumption in the short-run)
- long-run marginal costs (fixed in the short-run)

The essential idea behind "avoidable cost pricing" is that the consumer pays the costs that the utility would otherwise be able to avoid if the consumer's demand on the system were not present. In other words:

- If the consumer were connected to the system but demande[illegible] water and generated no sewer flows, he would still have to pay the fixed costs entailed in providing his connection to the system but he would not pay the utility for costs that vary with consumption.

- If the consumer demands services, he would have to pay for both the fixed costs and for the short- and long-run marginal costs that he generated. Extra long-run marginal costs are generated if he consumes services during peak periods.

A marginal cost peak period rate structure can be most simply devised by focusing on these concepts of avoidable cost. The rate structure employed in this study was as follows:

- fixed charge — all fixed costs
- commodity charge — all short-run marginal costs
  — a portion of long-run marginal costs
- peak surcharge — a portion of long-run marginal costs.

A major focus of empirical effort in this study was devoted to developing the "avoidable cost" data necessary to test this rate structure. The avoidable cost categories are further explained in the following three subsections.

a. Fixed Costs

The fixed costs are costs that do not vary with the quantity of water or sewer flows (e.g., postage cost for quarterly billings). These costs cannot be avoided by reducing demand; they are, in fact, "unavoidable costs." When fixed costs are a high proportion of total costs, pricing is less worthwhile because there is less avoidable cost at stake. Exhibit III-3 shows fixed cost as a proportion of total cost for the Potomac utilities. The proportion is very high, averaging 42 percent. This is one of the major factors affecting the results of this study. A large part of the cost of providing both water and sewer service is attributable to maintenance and replacement requirements of the in-

place treatment plants and pipelines. These costs do not vary with consumption and hence are unavoidable. A related feature of fixed costs is that the simplest way to charge for them is to divide total fixed costs by the number of customers to get a fixed per-customer service charge.

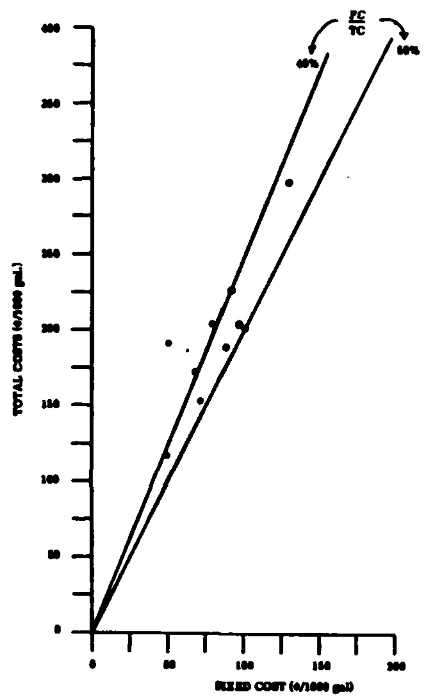


Exhibit III-3: FIXED COSTS AS A PROPORTION OF TOTAL COSTS

b. Short-Run Marginal Costs

Short-run marginal costs are current operating expenses that can be avoided by any reduction in demand. For example, the chemicals required to purify an extra gallon of water would not have to be purchased if that extra gallon were not demanded. Another characteristic of short-run marginal cost items is that they are generally the same in both peak and off-peak periods. That is, the same amount of chemicals are required per gallon of water (assuming equal quality raw water). There are some notable exceptions (discussed in sections which follow) but, in general, peak and offpeak short-run marginal costs are roughly equivalent. Therefore, it is not necessary to distinguish peak and offpeak consumption in designing a rate to recover these costs. Short-run marginal costs are included in a commodity charge which is applied to all water consumed in all seasons of the year on a straightforward cents-per-thousand gallons basis. Exhibit III-4 and III-5 present forecasts of the short-run marginal costs in Washington area utilities for water and sewer services, respectively.

c. Long-Run Marginal Costs

Long-run marginal costs are the capacity related costs of future new facilities. Capacity related costs include capital costs of new facilities, and operation and maintenance costs that are a function of capacity (such as the required number of operators). Some of this capacity is to be used predominantly to meet average day demand while the rest is present only to satisfy peak day demands. The long-run marginal cost must accordingly be divided into a commodity charge component, representing the portion of capacity used on a year-round basis, and a peak surcharge component representing the portion of capacity used only during the peak period.

Exhibit III-6 presents forecasts of the long-run marginal cost of new sewer capacity for Washington area utilities. The steeply upward sloping portions of these curves reflect the fact that sewage treatment capacity is very expensive.

Exhibits III-7 and III-8 present two sets of long-run marginal cost curves for new water supplies for the Potomac-user utilities. Exhibit III-7 shows very flat projections of the long-run marginal cost of new water supply. This is due to the effect of recent developments in supply management. Exhibit III-8 shows much steeper long-run marginal cost curves that represent roughly what future water supply costs had been

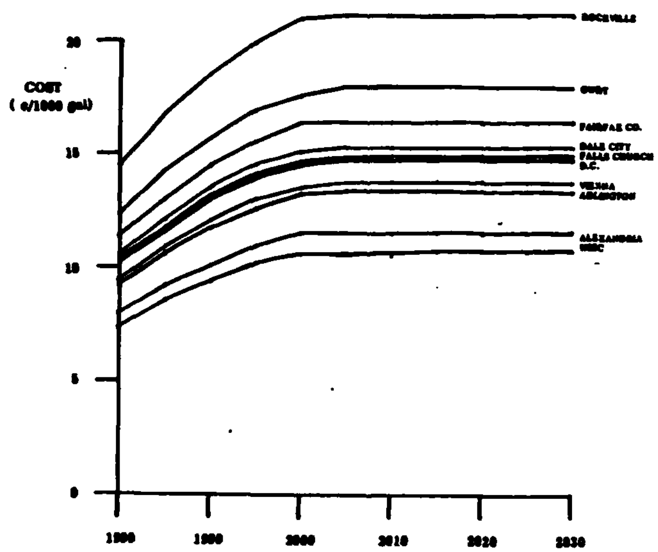


Exhibit III-4: WATER SHORT-RUN MARGINAL COST FORECAST
AT ZERO FLOW-BY

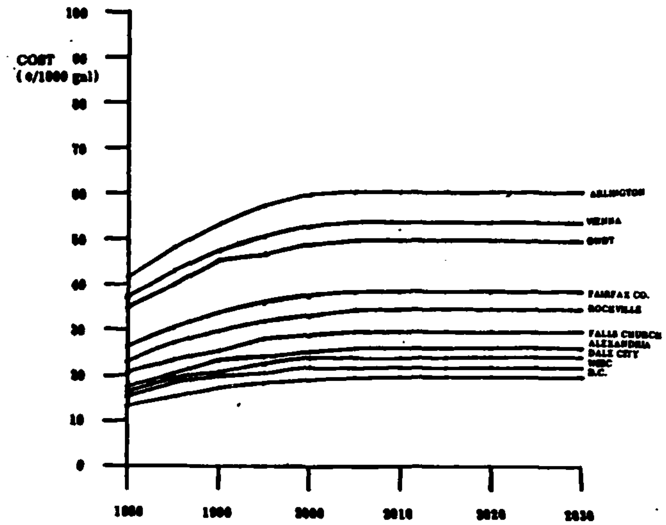


Exhibit III-5: WASTEWATER SHORT-RUN MARGINAL COST FORECAST

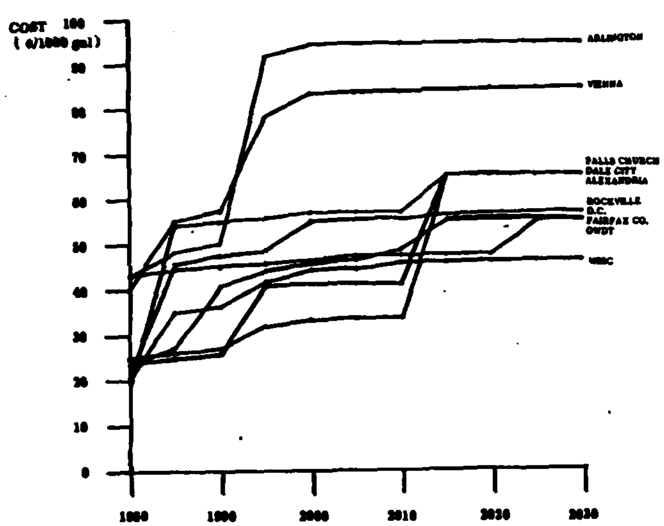


Exhibit III-6: WASTEWATER LONG-RUN MARGINAL COST FORECAST

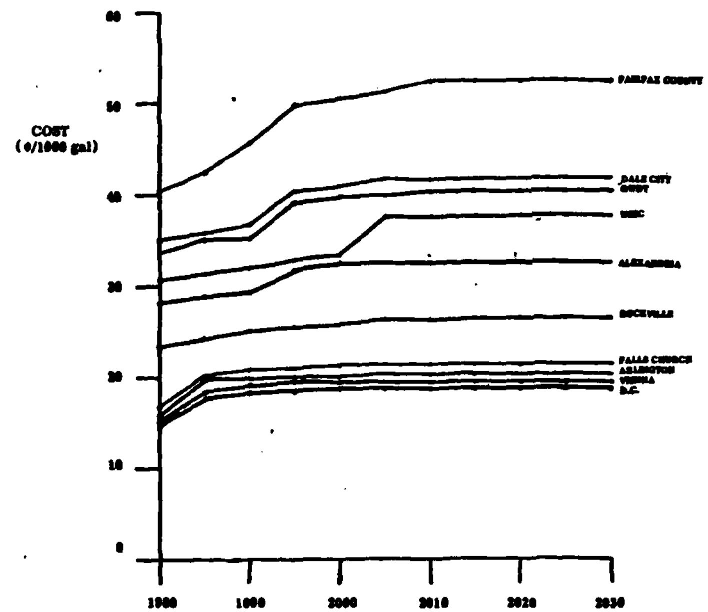


Exhibit III-7: WATER LONG-RUN MARGINAL COST FORECAST AT ZERO FLOW-BY

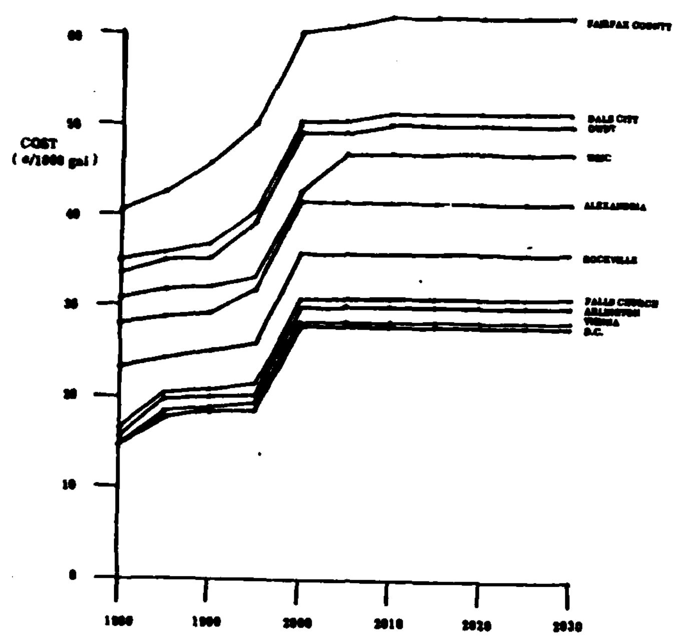


Exhibit III-8: WATER LONG-RUN MARGINAL COST FORECAST AT 300 MGD FLOW-BY

thought to look like a few years ago. The perception of the problem implicit in Exhibit III-8 was a large part of the impetus for this study of the role of pricing strategies in planning new water supply capacity.

4. Comparison of Existing Rates with Marginal Cost Peak Period Pricing

Exhibits III-10 through III-19, appearing at the end of this section, show the results of comparisons of existing rates to marginal cost peak period rates for the ten water utilities that depend upon Potomac water supplies. In each exhibit, four diagrams are presented. These represent rate comparisons at zero, 100, 300, and 600 MGD levels of flow-by. Before discussing individual results it is useful to first discuss them collectively to review their common characteristics.

Each diagram presents a future projection of the utility's average cost. Associated with this curve, there is an asterick on the vertical axis which represents the existing combined water and sewer rate at the time of this study (1980). It is possible to visualize a projection of future utility rates under current rate structures by assuming that the relationship of the asterisk to the average cost projection remains constant. There is presently a peak period rate in effect in Fairfax County and this is similarly projected into the future by assuming that it remains a constant percentage above the average cost projection.

Each of the diagrams in Exhibit III-10 through III-19 also presents projected winter and summer rates under marginal cost peak period pricing. These winter and summer rates are deserving of special note. Peak demand for water supply capacity occurs in the summer whereas the peak sewer capacity requirement is caused by infiltration in the winter season. The proper way to address these peaking characteristics from the standpoint of economic theory is with a summer peak charge for water and a winter peak charge for sewer. It may seem a bit absurd to think of charging a peak rate with the intent of affecting demand for sewer service, especially when the peak requirement is caused by infiltration. However, there is no getting around the fact that the opportunity cost of sewer consumption is higher in the peak period. More discussion of the sewer rate is given in Section C of this chapter.

Carver (7) found that the winter rate turned out to be much higher than the summer rate, reflecting the simple fact that sewage treatment capacity is more expensive. In the analysis performed here, flow data and interviews with utility personnel indicated that the sewer peak period actually extends throughout the fall, winter, and spring. Using this longer time period as a basis for the sewer peak charge produced "winter" rates that are lower than summer rates as indicated on the graphs in Exhibit III-16 through III-19.

For most of the Potomac-dependent utilities, the diagrams show that the summer rate under marginal cost peak period pricing is below the average cost curve at the 100 MGD level of flow-by. This means that marginal cost peak period pricing would not work as a strategy for raising prices to reduce water demand. Carver (7) obtained a similar result in his study. The reasons for this result can be explained with the help of Exhibit III-9.

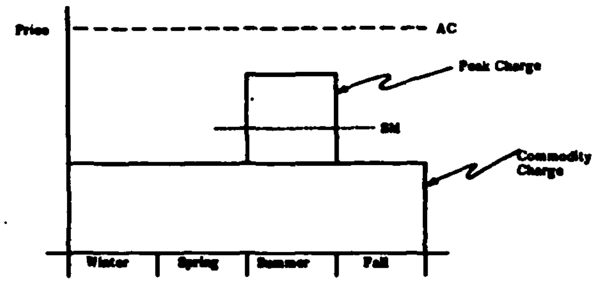


Exhibit III-9: INSUFFICIENCY OF MARGINAL COST PEAK PERIOD RATE

In this diagram, the area of the large rectangle represents the amount of costs included in the commodity charge portion of the marginal cost peak period rate structure. The area of the small rectangle represents the amount of costs included in the peak charge portion of the marginal cost peak period rate structure. As shown, the sum of the commodity charge and the peak charge (the summer quarter rate) does not equal the average cost.

There are two reasons for this. Not shown on the diagram is the fixed charge portion of the marginal cost peak period rate structure. The fixed charge is a fixed quarterly service charge per customer, regardless of usage. All that is shown on this diagram is the price the customer pays "at the margin;" the price of an extra unit of consumption (stated otherwise: the amount of money saved by conserving an extra gallon). One major reason that the average cost rate is higher than the marginal cost peak period rate is that it includes these fixed costs in the price charged at the margin; and, fixed costs amount to 40 or 50 percent of total costs in water and sewer utilities.

The other major reason why the summer peak rate falls short of the average cost is indicated by the dotted line marked "SM" in Exhibit III-9. The "SM" stands for supply management and the position of the dotted line is intended to illustrate the effect that the dramatic cost reductions made possible by supply management had on study results; a further reduction of the summer peak rate.

A few exceptions to these results can be noted in thumbing through the diagrams in Exhibits III-16 to III-19. In Dale City and the District of Columbia, the summer rate is about equal to the average cost rate at the 100 MGD level of flow-by. In both of these instances, this result is produced by the fact that fixed costs are comparatively lower for these two utilities. Both have older water distribution and sewage collection pipeline systems that have already been amortized; and, both jurisdictions are spending relatively little on maintenance and replacement. The result is lower fixed costs.

The peak summer rate calculated for Fairfax County Water Authority (FCWA) also exceeds average cost at the zero flow-by level. As a possible explanation, it is noted that the Fairfax County Water Authority data also exhibits a comparatively low proportion of fixed costs but the reason for this may be quite different than that for Dale City and the District of Columbia. The cost data provided by FCWA was probably the most detailed data acquired from all of the utilities studied. This may have produced a more refined estimate of fixed vs. variable costs. It is of importance to note that the summer peak rates calculated for FCWA are nevertheless below the current FCWA peak price in all flow-by scenarios.

For all other Potomac users the summer peak rates calculated are below average cost at the zero and 100 MGD levels of flow-by. The WSSC summer rate rises above average cost at the 300 MGD level of flow-by. The peak rate calculated for Falls Church also

rises above average cost at 300 MGD flow-by, but it does not exceed the level of the existing Falls Church peak charge. In all other Potomac-user cases, 600 MGD of flow-by or more must be assumed in order to produce a summer peak rate equal to average cost.

5. Elasticity of Demand

The empirical portion of this study was initially designed to include some effort to find the best available estimates of the elasticity of demand. This effort was later scaled back in view of the above described empirical results indicating that a change to marginal cost peak period pricing would not entail a price increase. Results of the limited investigations into the topic of elasticity are reported in Section III.D and in Appendix A (Vol. 2).

6. Interpretation of Empirical Results

Before offering interpretation of the meaning of the above described empirical results, it is appropriate to consider the limitations imposed by potential sources of error and the effect of sensitivity analyses at different levels of flow-by. The following points are noteworthy in this respect:

- Error may be produced in the cost estimates due to the following factors: (1) the minute level of detail required for pricing analysis was often not available and various assumptions were substituted; (2) cost accounting by utilities differs from the approaches used here which may cause utilities to view their costs differently; (3) forecasts of future costs, especially over the long-term, are subject to greater uncertainties.

- Cost estimates used reflect no extra premiums to cover intangible external costs except that environmental flow-by is included. Otherwise, environmental costs of water supply projects or other side effects of urban growth are not included.

- There is some indication that pricing might be more viable at a 300 MGD level of flow-by. This level may be required if: (1) there is error in the estimated level of flow-by needed for water quality maintenance; (2) there is error in the forecast of regional demand growth; (3) there is error in the estimated effectiveness of supply management.

Given these qualifiers, the empirical conclusions of this study may be summarized as follows:

- It appears that marginal cost peak period pricing is not a viable means of reducing demand in the near-term, due primarily to the cost-savings of supply management.

- Over the mid-term, say the year 2000, numerous factors forming the basis of this analysis may change. It would be prudent to re-evaluate pricing strategy on a regular basis; this can best be performed, however, by individual utilities.

The following recommendations are made to enable utilities to be in a better position to recognize and take advantage of pricing opportunities in the future:

- Better tracking of cost data according to "avoidable cost" categories would permit more accurate assessment of pricing policies.

- More extensive forecasting of future costs would improve the quality of pricing analysis and permit utilities to view the future in terms of their own inflation and interest rate assumptions.

- Greater study of options for modifying billing practices to coincide with peak periods would refine ability to design peak period pricing strategies.

- More extensive economic research and data collection on demand elasticity should be performed to improve the ability to forecast the effects of pricing policies.

The remainder of this chapter presents descriptions of the methodologies employed in the empirical efforts for: (1) development of cost estimates (Section B); (2) calculation of marginal cost peak period rates (Section C); and, (3) review of the topic of elasticity (Section D).

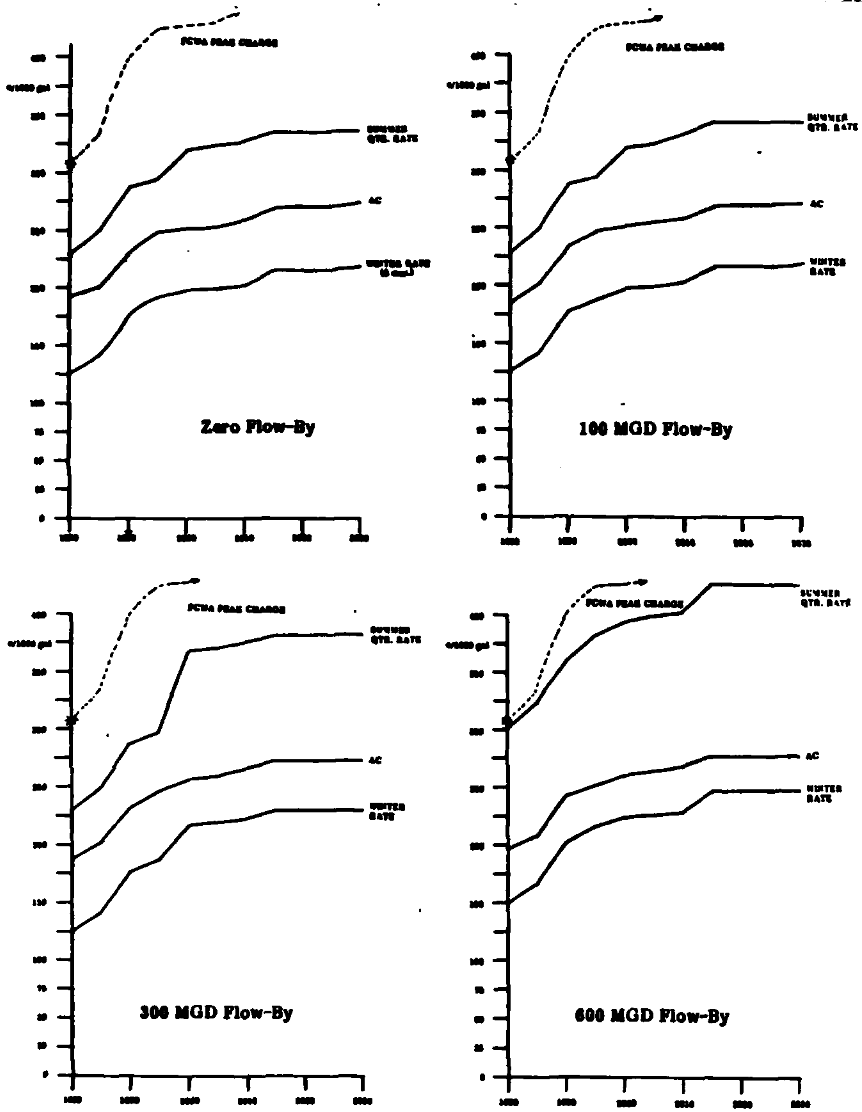


Exhibit III-10: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: FAIRFAX COUNTY

III-19

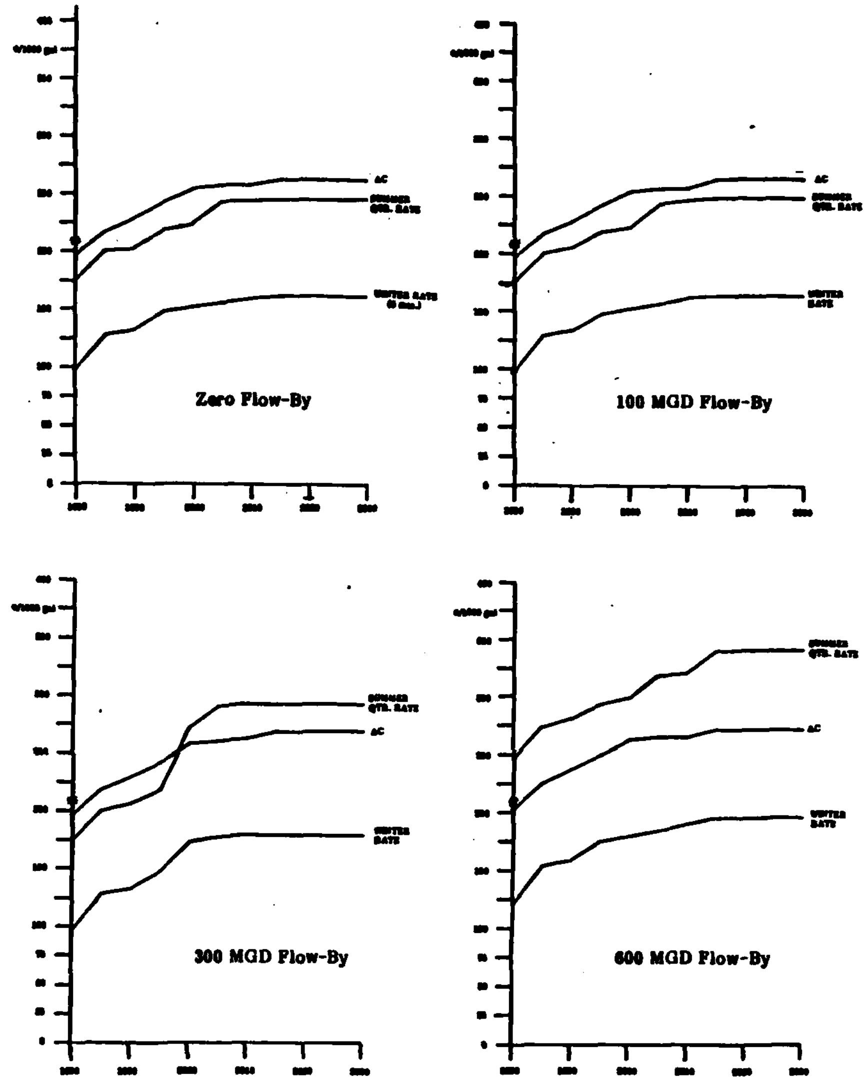


EXHIBIT III-11: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: WSSC

III-20

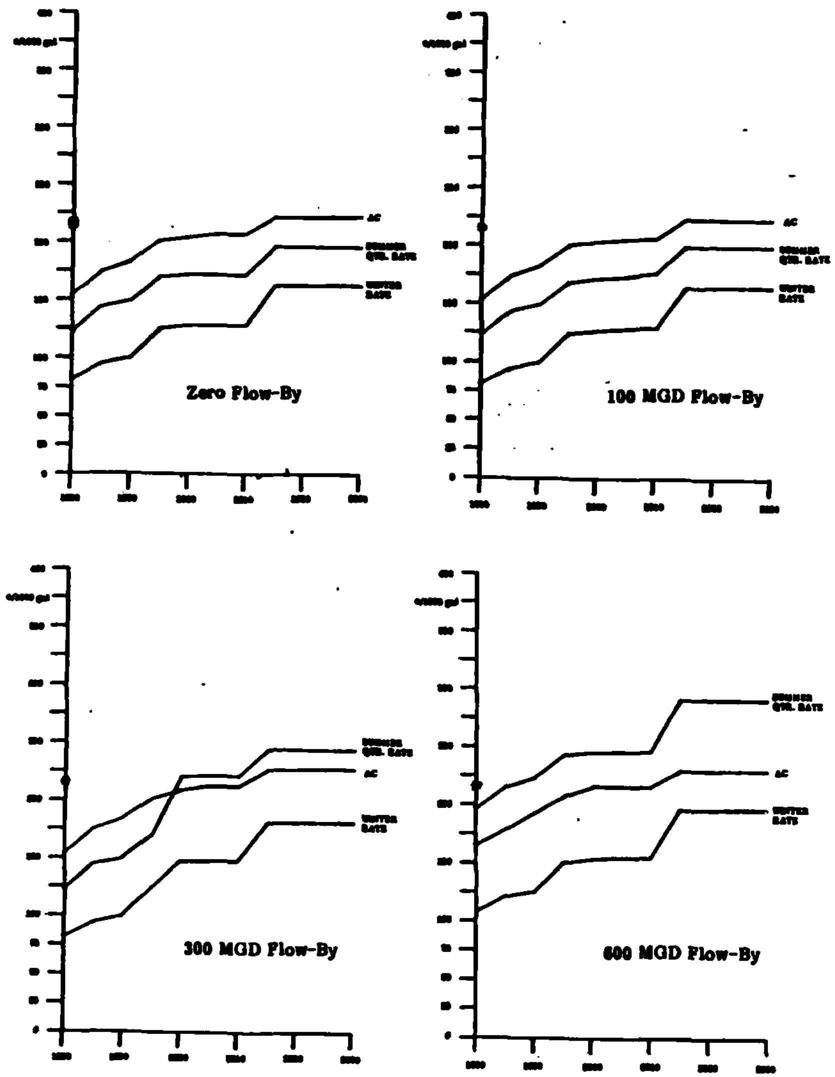


EXHIBIT III-12: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: FALLS CHURCH

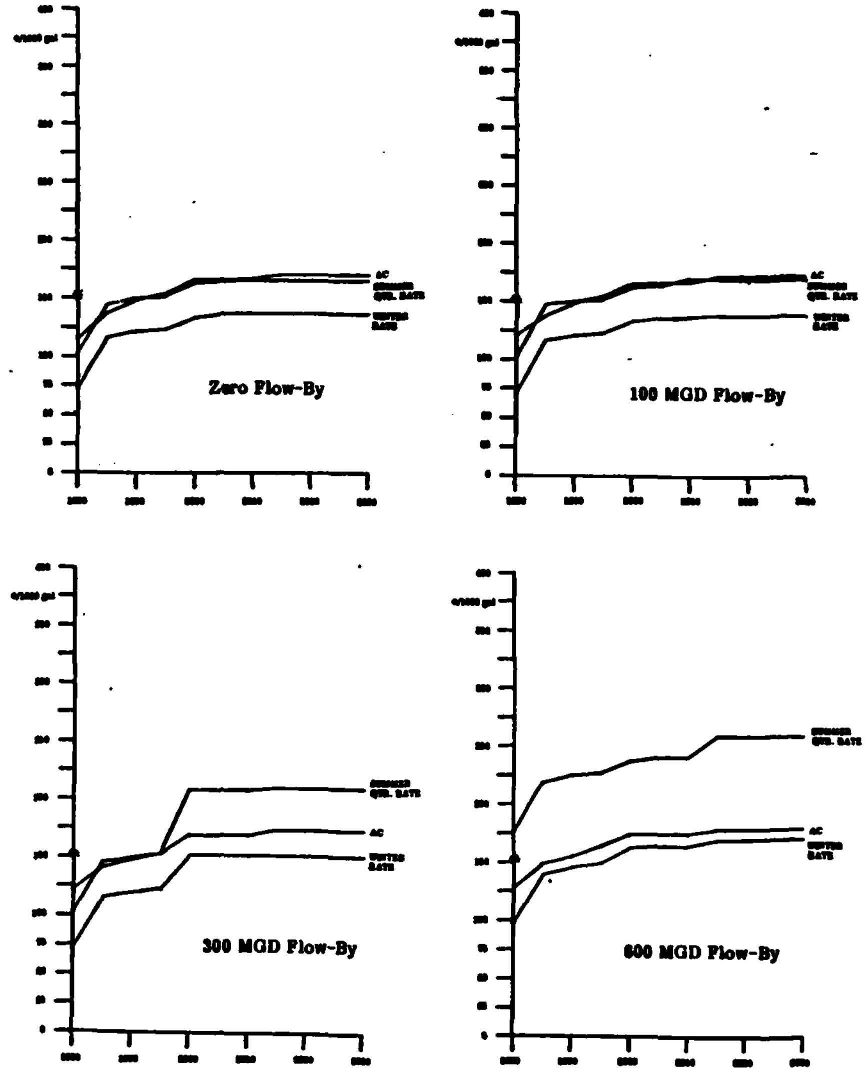


EXHIBIT III-13: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: D.C.

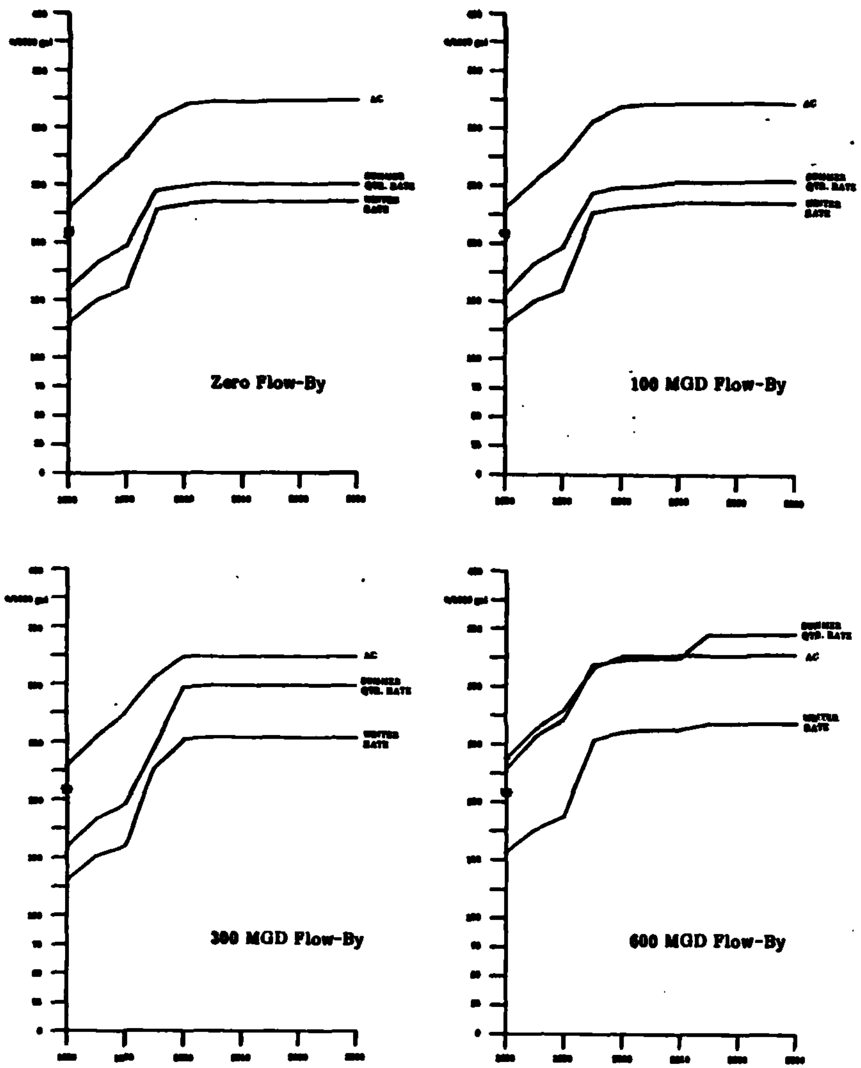


EXHIBIT III-14: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: ARLINGTON

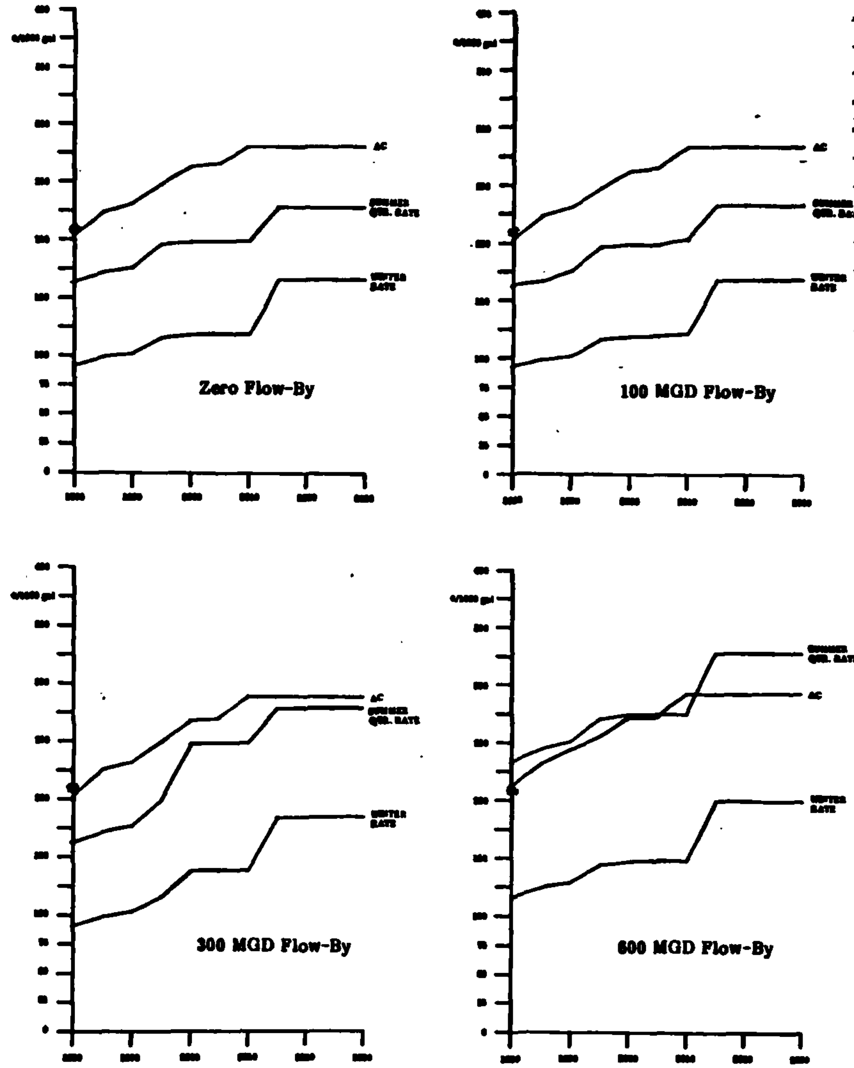


EXHIBIT III-15: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: ALEXANDRIA

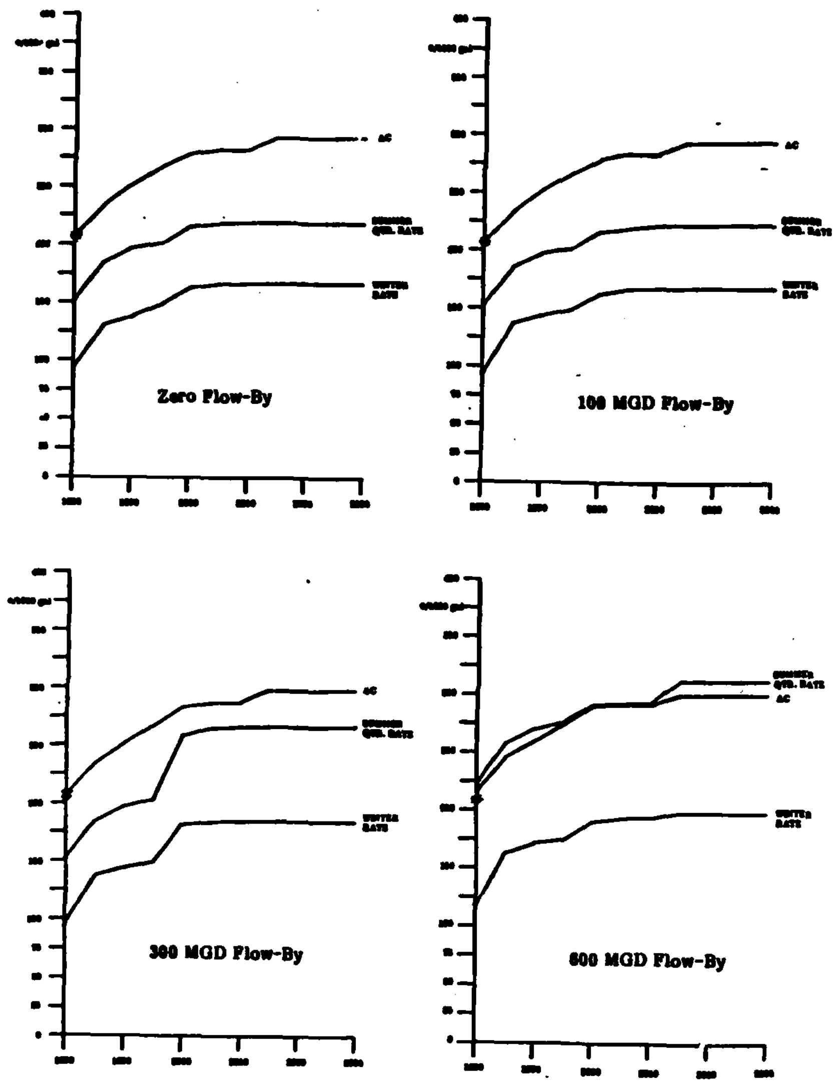


EXHIBIT III-16: EXISTING RATES VS. MARGINAL COST PEAK
PERIOD RATES: ROCKVILLE

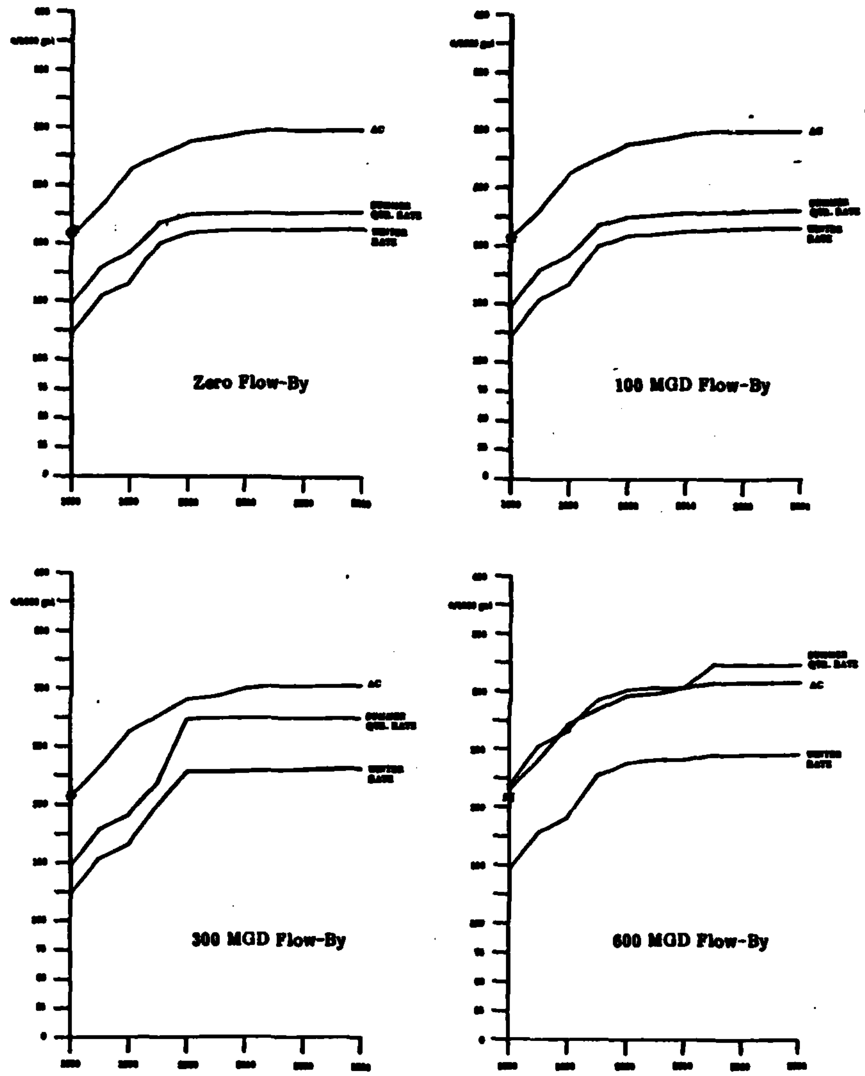


EXHIBIT III-17: EXISTING RATES VS. MARGINAL COST PEAK
PERIOD RATES: VIENNA

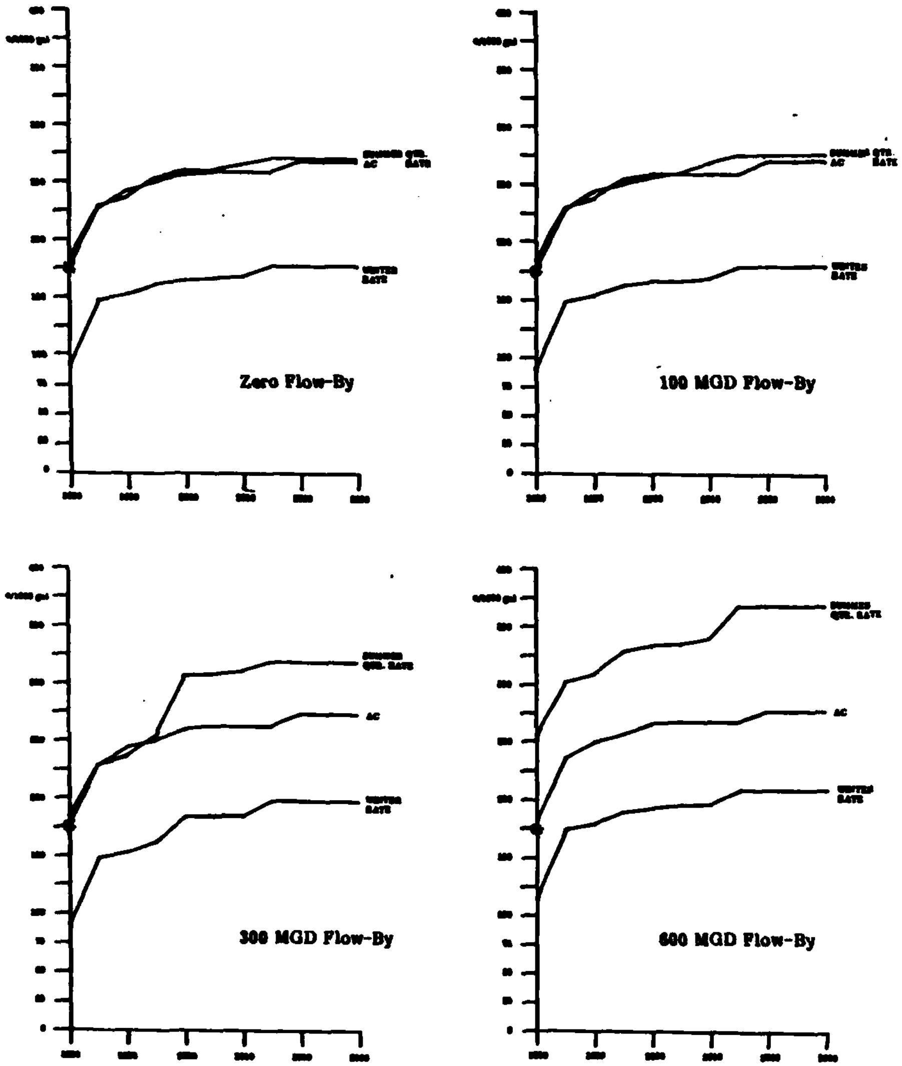


EXHIBIT III-18: EXISTING RATES VS. MARGINAL COST PEAK
PERIOD RATES: DALE CITY

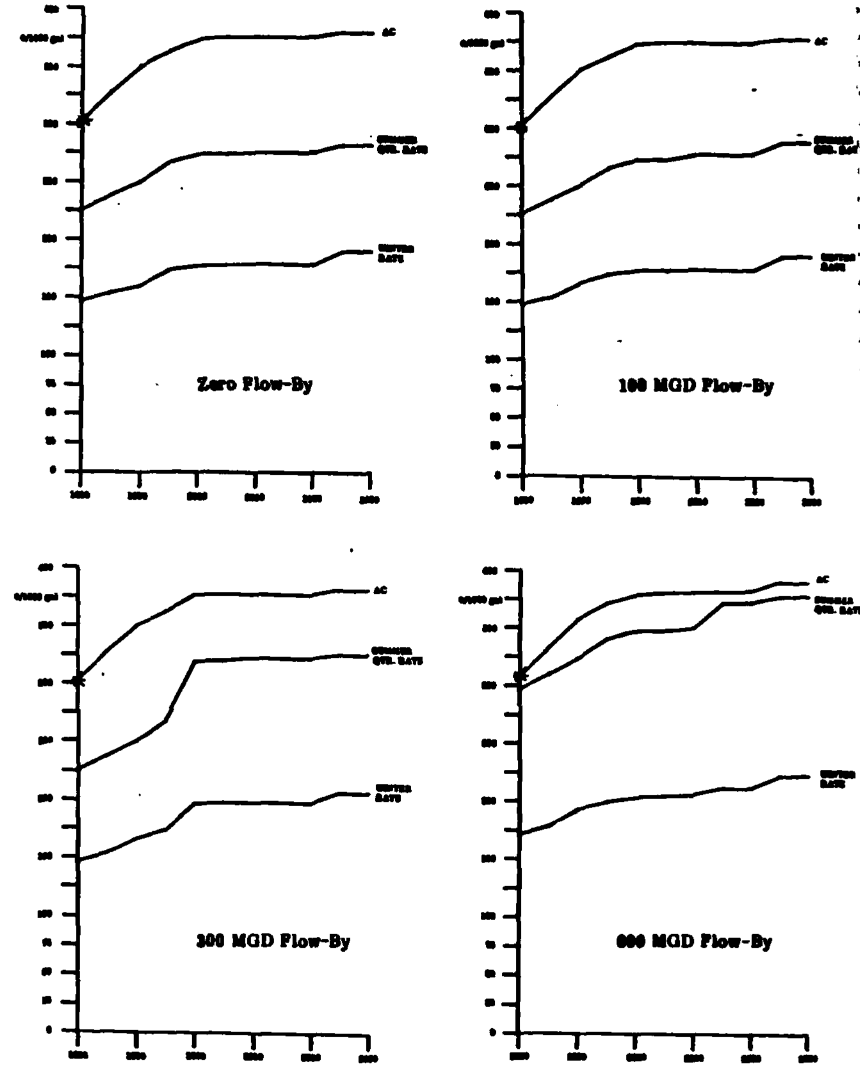


EXHIBIT III-19: EXISTING RATES VS. MARGINAL COST PEAK
PERIOD RATES: OWDT

B. COST ESTIMATES

1. Introduction

a. Scope of the Task Undertaken

This study was designed as a first-cut broad sweep of the problem of assessing the potential role of pricing strategies in water supply planning within the Washington, D.C. metropolitan area. The scope of work entailed estimating current and future costs and rates for both water and sewer services in 22 utility service areas (10 Potomac users and 12 non-Potomac users reported in Appendix D), study of current rate designs and rate history, evaluation of alternative rate designs, evaluation of available data regarding observations of the elasticity of demand, and evaluation of the potential to reduce demand through better pricing allowing deferment of new water supply projects.

The cost estimation task ultimately amounted to over 50 percent of the total effort. Preliminary results began to indicate that rates based on marginal cost peak period pricing might not equal present prices. Emphasis was shifted from analysis of elasticity to further cost analysis in an attempt to test the sensitivity of the preliminary results. Estimates of "avoidable costs," the basis of marginal cost peak period rates (see Section III.A.3), were developed with a deliberately conservative high bias. Yet, the results remained unchanged.

Despite the emphasis on cost analysis the level of effort was still spread thinly over 22 utilities. The topical scope of investigations was similar to that entailed in a cost-of-service study. However, the budget available for this task was equivalent to what one mid-size utility might pay for such work. The comparison of the depth-of-cut or level of detail achievable, therefore, is on the order of one-twentieth or less. In reviewing the literature, similar case study projects sponsored by EPA and the Corps of Engineers appear to have applied a greater per-case-study level of effort.

It is felt, nonetheless, that the estimates developed in this study are suitable for a first cut at the problem. This is especially true in light of the fact that much of the focus was on developing conservatively high cost estimates which is in some ways easier than developing precise estimates. However, there is a need to solicit serious review of the

products of this effort in order to refine ideas about potential second-cut efforts that may be worthwhile. In this regard, a conclusion of this analysis is that the development of "avoidable cost" accounting practices by the utilities is the best next step that can be taken to assure that present or future opportunities for pricing are not missed. Utility staff have the greatest familiarity with their system cost data and are also in the best position to make the difficult judgement calls that can be involved in estimating some categories of "avoidable costs."

b. Taking Inflation Into Account

As presented in the beginning of Chapter II, water and sewer utilities in the Washington region have experienced a trend of rapidly escalating costs over the period of the last decade. As further elaborated in Chapter II, this trend has become so prominent that it affects most everyone's expectations about the future. Though a complex of factors including EPA standards, continued urban growth, and resource limitations, contribute to this trend of rising costs, inflation is often the first villain to be named. Thus it was determined at the outset that this study should take explicit account of the effect of inflation.

In the traditional approach to the economic discipline of project analysis, inflation is deliberately ignored. From the standpoint of Federal projects, it is reasoned that the Federal government cannot plan on the basis of sustained inflation for to do so would be an admission of its inability to manage the economy. From a local government or utility standpoint, it is reasoned that if inflation continues over the life of an investment project, the utility actually gets a bargain by being a debtor, especially at usually low bond interest rates. Over the last half of the last decade, some attention has been paid to strategies by which utility financial planners can actually try to take advantage of this condition.

The basic question addressed by this study is whether pricing strategies can depress demand sufficiently to defer the need for new supply projects. The reaction of some observers of utility finances is that deferment of capital projects only results in an inflated and more expensive construction bill (in real terms) at a later date. To evaluate this question, it is necessary to ascertain the net difference between the inflation rate of water and sewer facilities and the general rate of inflation in the economy. Comparisons of EPA, ENR (Engineering News Record), and other indices with

the CPI (Consumer Price Index) revealed a net escalation rate of two percent (i.e., water and sewer works are inflating at a rate that is two percent above the general rate of inflation). Comparable analysis of indices for O&M costs show a three percent net escalation rate there. Projecting 50 years into the future, it is inconceivable to an economist that such a net escalation rate could be sustained in any sector of the economy. Such a gap would sooner or later attract other producers to enter the market or encourage existing producers to expand, thus bringing costs back into line with the rest of the economy. Reflecting this theory, the following assumption was used: net escalation rates will decline to zero by the midpoint of the planning period (2005) at a uniform rate.

Summarizing, the approach for taking inflation into account was to use the above escalation assumptions to project costs in constant dollars, producing curves like that in Exhibit II-3. Use of constant dollars requires a difficult discount factor. It is not as easy to pick a "real" rate of interest with which to convert capital investments into annual payments when working in terms of constant dollars. In this circumstance it is appropriate to use an estimate of the "real" rate of interest which is not comparable to present utility bond rates or Corps of Engineers planning rates. An estimate of three percent was selected for use in this study. Further details are given in the technical footnotes contained in Appendix A.

c. Taxonomy of Costs

As a first-cut effort at applying economic principles of pricing according to "avoidable cost" (or opportunity cost), it was necessary to develop a completely original cost data base for the Washington area utilities. Cost data is usually developed and maintained by engineers and accountants or financial analysts. These professionals generally employ a cost vocabulary and a system of accounts which is useful to the economist as a starting point but which lacks many needed pieces of information. The missing information pertains to certain details needed to specify cost concepts that are unique to the economist and not of interest to accountants and engineers for their routine purposes.

To estimate the "avoidable costs" of water and sewer service consumption, requires first that cost data be organized by function. The functional subsystems involved are:

- water supply source
- water treatment
- water distribution
- wastewater collection
- wastewater treatment
- administration

Many utilities have good operating cost data organized by functional category. Some smaller utilities do not keep such data in as readily usable form.

For all utilities it is very difficult to get data on how capital costs are distributed across these functions. The common financial practice is to lump all capital projects together into an annual bond issue; and, after many such bonds it becomes difficult to guess the precise functional mix of capital spending. Some effort was expended reviewing past bond issues but this could not be sustained within the project budget. Furthermore, the last several years of bond issues are only a snapshot of capital spending which could be misleading if the mix of spending is unrepresentative.

Capital budgets are similarly only snapshots of planned expenditures for the next five years or so. Data on depreciation by functional category was developed by EPA in an intensive study of the major Washington area utilities (8). This data, together with occasional clues from bond issues, was used where utility managers could not offer a guess.

Beyond the need for operating and capital cost data by function, determination of avoidable costs required that each of these cost items be further broken down into short-run variable, long-run variable, and fixed components. The result of this process was a set of twenty cost categories listed in Exhibit III-20. Estimation of costs in these categories was a long and difficult task which relied heavily on the judgement of those utility managers who were willing to venture an answer to questions seldom heard before. Engineering judgement by our engineering subcontractor was also employed to plug many of the gaps with estimates. The definitions of the twenty categories, however, were specified by the economists on the study team. These category specifications are described by functional group below.

Exhibit III-28: COST CATEGORIES

Categories		Descriptions
Water Short-Run M.C.		
Water Source O&M (flow)	-	ex. raw water pumping
Water Treatment O&M (flow)	-	ex. chemicals
Water Distribution O&M (flow)	-	ex. finished water pumping
Water Long-Run M.C.		
Water Source Capacity	-	new supply projects
Water Source O&M (capacity)	-	ex. maintenance crew for a new reservoir
Water Treatment Capacity	-	new treatment plant capacity
Water Treatment O&M (capacity)	-	ex. labor to staff new plant
Water Transmission Capacity	-	new transmission mains
Water Transmission O&M (capacity)	-	ex. line maintenance for new main
Sewer Short-Run M.C.		
Wastewater Treatment O&M (flow)	-	ex. chemicals
Wastewater Collection O&M (flow)	-	ex. pumping
Sewer Long-Run M.C.		
Wastewater Treatment Capacity	-	new wastewater treatment plant capacity
Wastewater Treatment O&M (capacity)	-	ex. labor to staff new plant
Wastewater Collection Capacity	-	new sewage collection mains
Wastewater Collection O&M (capacity)	-	line maintenance for new mains
Fixed Costs		
Administration	-	ex. general administration, billing, etc.
Water Distribution Capacity	-	unretired costs of existing water distribution system
Water Distribution O&M (fixed)	-	line maintenance on fixed distribution system
Wastewater Collection Capacity	-	unretired costs of existing wastewater collection system
Wastewater Collection O&M (fixed)	-	line maintenance on fixed collection system

Notes:
O&M (flow) = O&M costs that are a function of flow
O&M (capacity) = O&M costs that are a function of new capacity
O&M (fixed) = O&M costs that are a function of fixed capacity

(1) Water Supply Source

For the major Washington utilities dependent upon the Potomac River, costs for water supply source development and operation were taken from Corps of Engineers data. This task was made more difficult by new advances in supply management which made previous Corps supply scenarios and cost projections obsolete. New scenarios and required changes in costs were developed with the Corps. These efforts are reported in subsection 3, below.

Water supply project costs were dissected into three categories:

- water source capacity cost
- water source O&M (capacity)
- water source O&M (flow)

Capital costs of water source capacity were projected into the future on a scenario basis to produce long-run marginal cost curves like that of Exhibit II-3. Inflation of construction costs was accounted for in the manner described earlier.

Water source operation and maintenance costs were divided into those that are a function of flow such as raw water pumping, and those that are a function of capacity such as reservoir maintenance personnel. In general, water source O&M costs that are a function of flow are short-run marginal costs that should be charged in the commodity charge because they are avoidable for any reduction in demand. In the case of pumping costs, however, there are two instances in which part or all of short-run marginal costs should be included in the peak charge. The first case is when the peak water demand period coincides with the electric utility peak load. Pumping costs are higher due to peak electricity rates and the extra cost should be charged in the peak charge. Though a few utilities had high costs for water transmission, peak electricity use was not a major cost item for most utilities. The other case in which water source pumping costs are attributable to the peak is the unique case of the Corps of Engineers raw water interconnection projects. In these projects where pumps are used exclusively to expand peak storage capability, the entire pumping cost is attributable to the peak.

(2) Water Treatment and Wastewater Treatment

Water and wastewater treatment facilities have similar profiles of avoidable costs. Three categories are distinguished as follows:

- water/wastewater treatment capacity cost
- water/wastewater treatment O&M (capacity)
- water/wastewater treatment O&M (flow)

As with water supply source costs discussed above, capital costs of capacity are projected into the future to produce a long-run marginal cost curve like that in Exhibit II-3. Operation and maintenance expenses must once again be divided between those that are a function of flow and those that are a function of capacity. For example, the number of trained operators required to operate a plant is a function of capacity and this labor cost should be considered a long-run marginal cost item. They are avoidable if new plants are not built or are deferred.

On the other hand, chemicals and power are short-run marginal costs that should be included in the commodity charge. These costs can be avoided by any reduction in demand. An investigation was performed to determine if some of the short-run marginal costs of chemicals and power might be attributable exclusively to the peak. This was found to be insignificant and all short-run marginal costs were charged in the commodity rate.

(3) Water Distribution and Wastewater Collection

Costs entailed in the distribution and collection systems have very different characteristics from the standpoint of avoidability. Five categories of costs are required:

- capital costs for new capacity
- capital costs for existing capacity
- O&M costs that are a function of new capacity
- O&M costs that are a function of existing capacity
- O&M costs that are a function of flow

It is often difficult to segregate different aspects of capital cost responsibility in distribution and collection systems. There is a gradient of responsibility that varies from 100 percent individual responsibility at the point of connection to some degree of

shared responsibility for the sizing of major transmission mains. In the middle of this gradient, there are some facilities that are sized for peak hour flow (which cannot be metered) or are sized to meet fire protection standards. Some approaches to this problem have followed a simplifying assumption which regards the entire distribution and collection systems as fixed cost items. Analyses undertaken in this study attempted to sort out some of the avoidable costs. The conclusions were: to disregard costs of new connections, for these are, quite properly, covered by connection charges in most all utilities; to regard the middle part of the gradient as fixed cost; and to count capital costs for major new transmission mains or trunk sewers as long-run marginal costs.

A frequently debated aspect of utility financing is the apparent injustice of spreading part of the cost of expanding a transmission main or trunk sewer over existing customers when new customers are responsible for the system growth. The economist would agree that pricing on the basis of geographic cost responsibility is an optimal approach. However, geographic pricing is not institutionally feasible in many cases. For this study, only expansions of existing transmission mains or trunk sewers were counted as long-run marginal costs. Expanding service to entirely new areas was not included as these costs are generally charged to real estate developers. For the expansion of existing mains and trunk lines, however, the cost of the expansion could be avoided by reduced peak demand from either existing or new customers. Therefore, this opportunity cost must be charged to both classes of users alike. It should be noted that study results were not very much affected by this procedure. The proportion of total distribution and collection system costs eligible for this treatment was found to be small. This step was included in the methodology, however, to ensure that all conceivable avoidable costs were counted.

The operation and maintenance costs associated with the distribution and collection systems were similarly divided between those related to existing capacity and those related to capacity expansions. O&M costs of the existing system were treated as fixed costs while O&M costs for new capacity were counted as long-run marginal costs.

The short-run marginal costs of water and sewage pumping are the only O&M costs of distribution and collection that vary with flow. These costs were included in the commodity charge as it was found that extra costs of electricity during peak period was not a significant factor in most cases.

(4) Administration

Overhead costs of administration such as billing, planning staff, and management staff are all fixed costs of utility operation which cannot be avoided.

2. Utility Cost Data

An original methodology was developed for converting utility cost data into the data base required to support "avoidable cost pricing." This section describes these methods in broad outline. Data development for costs of new water supply projects is the subject of subsection 3, below.

a. Data Collection

The basic data collection effort applied in this study consisted of contacting the utilities, acquiring their available budget data or other financial summaries, and soliciting the judgement of key utility personnel to help make some of the tough decisions needed to sort costs into the twenty categories and to project capacity growth 50 years into the future. The study's data needs were confusing to some utility personnel and there was some understandable irritation at being bothered by the n^{th} study of the Wasington water supply problem. Yet, overall, utility personnel displayed an incredible amount of patience and continued to cooperate fully even when subjected to several nuisance follow-up calls. The study team owes these people a great debt of gratitude.

b. Projections

As discussed earlier, costs were projected into the future to ascertain whether the trend toward rising costs would make pricing strategies more effective in reducing demand. This was done on a constant dollar basis in order to take account of the effect of inflation.

Net escalation rates were developed for capital and O&M expenses. O&M costs were simply escalated into the future on a cents-per-thousand-gallons basis. Capital costs for new additions to capacity were escalated from the present out to the year of construction and then annualized at the real rate of interest. These capacity costs were then converted to a ¢/1000 gallon basis to produce long-run marginal cost curves.

Average costs were projected into the future using these same procedures for escalating both O&M and capital costs. However, for the capital costs, the cost of the new capacity is averaged in with the cost of existing capacity to give future average cost.

c. Problems Encountered

Exhibit III-21 illustrates the most basic problem encountered in the development of cost data for this study. The figure shows the complicated interlocking network of water and sewer service areas and facilities in the Washington area. Because of this circumstance, many additional data sources were involved in the cost analysis, and very tedious aggregations and disaggregations of "pieces" of the desired information were entailed in producing results on a service area by service area basis.

In order to figure out the interconnections shown in Exhibit III-21, it was necessary to develop a detailed water balance accounting for all water and wastewater flows indicated. Then, in order to project costs into the future it was necessary to project changes in the water balance over time. For this step, it was found that the regional 208 Plan provided the best guidance on future facility expansions and the population growth assumptions used are roughly comparable to the Corps water demand forecast used to schedule water supply capacity expansions.

The utility interconnections also posed a theoretical problem in the determination of long-run marginal cost. If a utility uses two different wastewater treatment plants and both are to be expanded, what should be used as the long-run marginal cost? In electric utility problems the higher cost plant expansion is used for an estimate of marginal cost because it would surely be cancelled first if demand suddenly dropped off. Water and sewer service cannot be easily transferred between plants however. The geographic constraint suggests that a weighted average of the two long-run marginal costs should be used. This was the approach selected.

An additional complication of study methodology and results was produced by the need to present costs on a ¢/1000 gallon basis. This is a useful basis for performing some types of cost escalations, for calculating certain weighted averages, and for rate calculations. The concepts of cost that were sought often underwent considerable evolution during the course of the study as the engineers and economists exchanged

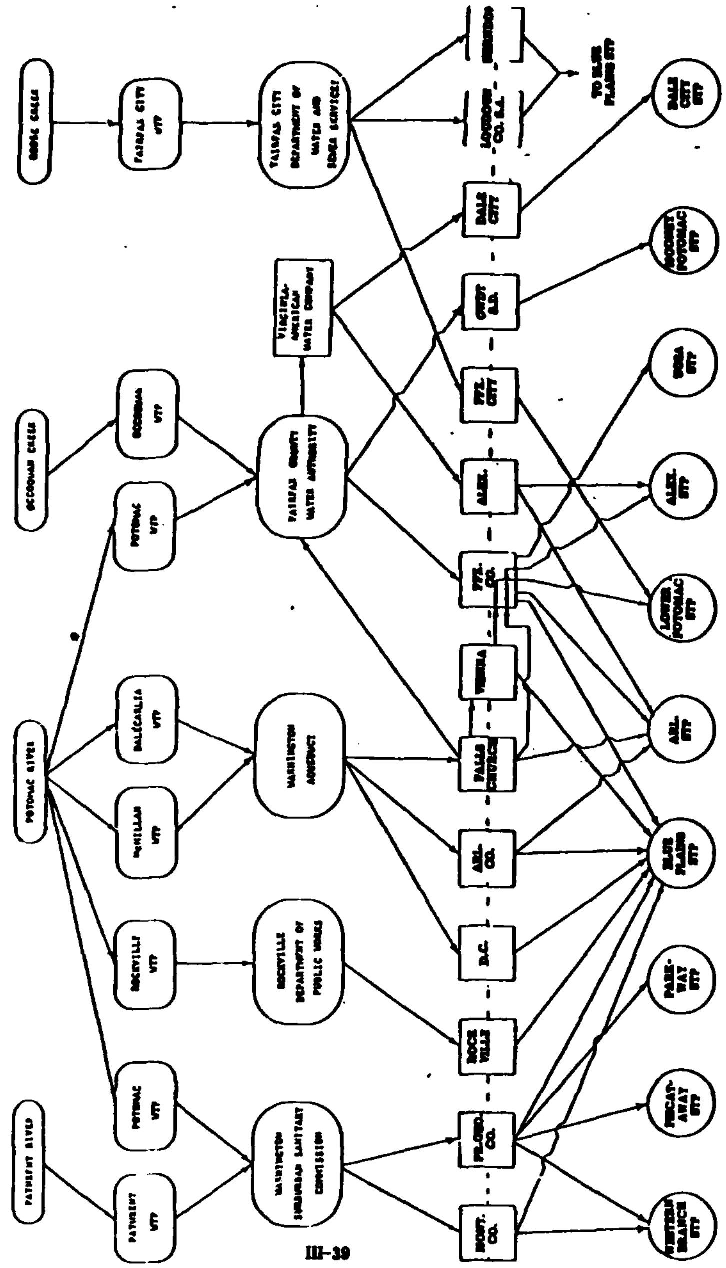


Exhibit III-21: INTERCONNECTIONS OF WATER AND WASTEWATER UTILITY SYSTEMS IN THE METROPOLITAN WASHINGTON AREA

*FFX. CO. Potomac intake is not yet on-line. Another new Potomac intake is proposed for Leesburg.

understandings. Unfortunately, some misunderstandings were not corrected until late in the process. When working on a ¢/1000 gallon basis, it is easy to get confused about the proper denominator. Upon receipt of the engineering subcontractor's report, it was found that several categories of estimates had to be corrected before use in rate calculations. The engineering subcontractor's report, incorporated as Appendix B, has been included for further information on various points of methodology but the results section was deleted due to these errors. In reviewing the further methodological discussion presented there, the following corrections should be noted:

- Water source capacity costs, and water source O&M costs that are a function of capacity should be divided by capacity, not flow.

- All O&M costs that are a function of capacity should use capacity in the denominator, not flow.

- Wastewater treatment capacity costs should use peak capacity in the denominator, not design (average day) capacity.

The correct cost forecasts are tabulated in Appendix C.

3. Water Supply Cost Data

a. The Need for Scenario Development

As mentioned in Chapter I, the U.S. Army Corps of Engineers in the early 1960's considered the development of 16 major reservoir sites on the upper Potomac, in order to assure an adequate water supply for Washington, D.C. Throughout the 1970's, studies by the North Atlantic Division and Baltimore District Corps offices further refined the technical analyses and examined a broad range of alternative types of water supply projects. The Corps has also reassessed demand forecasts and the potential for conservation, concluding in 1979 that perhaps only two or three new projects may be needed over the next fifty years. Just recently, however, new research in supply management (coordinated timing of reservoir releases to optimize storage capacity) has demonstrated that it is possible to satisfy demand through the year 2030 with the addition of only one new locally sponsored storage project and the implementation of several other measures.

At the time this pricing study was conceived, it was anticipated that water supply scenarios and associated costs given in the Corps Draft Progress Report (4) on the Metropolitan Washington Area Water Supply Study (August 1979) would be useful as input data. The structural components of the scenarios described in that report featured the newly completed Bloomington reservoir, the proposed Little Seneca Lake, and raw water pipeline interconnection projects between the Potomac River and either the Patuxent or Occoquan reservoirs. With new developments in supply management, however, only Little Seneca Lake would be required.

As mentioned elsewhere in this report, the conventional wisdom regarding the future of urban water supplies holds that they will become increasingly expensive as the most accessible supplies are exploited. The previous Corps scenarios also conveyed this impression. The pipeline interconnection projects scheduled to be built after Little Seneca Lake were much more expensive than reservoir supply.

A part of the conventional wisdom mentioned above is that pricing strategies are perceived to have an important role to play in forcing consumers to recognize that availability of water supply resources is becoming more constrained. Higher costs should produce higher prices which should encourage greater efficiency in the use of the resource. However, the removal of the higher-cost supply alternatives from future scenarios diminishes the potential efficiency gain from better pricing. Furthermore, by optimizing the storage capacity available in reservoirs like Bloomington and Little Seneca, supply management also decreases the unit cost of these facilities because more water is produced at practically the same cost. Thus, the advances in supply management are one of the most important factors affecting the results of this study.

The most immediate impact of supply management on the course of this study was the need to produce an entirely new set of water supply scenarios and costs for analysis. The addition of this task was fortunate in some respects because there are several economic concepts entailed in structuring supply scenarios which were brought to light. The National Academy of Sciences (NAS) committee reviewing the Corps water supply study had suggested that the Corps pay some attention to regionalized institutional approaches and had called for an overall benefit/cost analysis of the problem. Both topics were touched on in developing scenarios for analysis in this study. Findings of these investigations were reported in the theoretical presentations of Chapter II.

b. The Draft Progress Report Scenario Development Process

As a starting point for developing new scenarios, the scenario development process employed in the Draft Progress Report was examined. This process is pictured in Exhibit III-22. In steps 1 and 3, assumptions about conservation, population growth, and water consumption characteristics were combined to produce demand forecasts for all utilities in the region. The economist notes that the relationship of price to demand is not sufficiently accounted for in this methodology. The feedback loop indicated by the dashed line emanating from step 7 was not an actual step in the Draft Progress Report methodology.

Steps 2 and 4 specified the supplies available to the utilities. In step 2, an initial amount was deducted from available Potomac flow for environmental "flow-by" into the estuary. This amount was 100 MGD that was deemed necessary to flow past (flow-by) the water intakes and on into the estuary to provide flushing for maintenance of water quality. The remaining Potomac flows were then allocated in step 4 according to the terms of the Potomac River Low Flow Allocation Agreement (LFAA). This agreement allocates available supplies from the Potomac as well as from the Patuxent and Occoquan reservoirs to utilities on the basis of their five-year rolling average winter season demand.

Deficits resulting from imbalances between supply and demand were calculated on a utility by utility basis in step 5. It should be pointed out that the design condition selected for supply and demand analyses, and therefore represented in the deficits, was a once-in-one-hundred-year, seven-day drought event. This level was jointly selected by the Corps and the utilities and seems to represent a considered judgement on the level of shortage cost sufficient to justify building new capacity.

Steps 6, 7, and 8 offered a number of alternative ways of satisfying the utility deficits. The alternatives featured different institutional approaches ranging from local action by individual utilities, to subregional cooperation by two utilities, and full regional cooperation by all utilities. In all alternatives, the cost allocation rule was that utilities shared in the cost of a project in proportion to the amount of project capacity they required. The intent was to produce equity among utilities. In some local and subregional scenarios equitable cost allocation did not result, however, because some utilities were constrained by geography to share in more expensive projects than others.

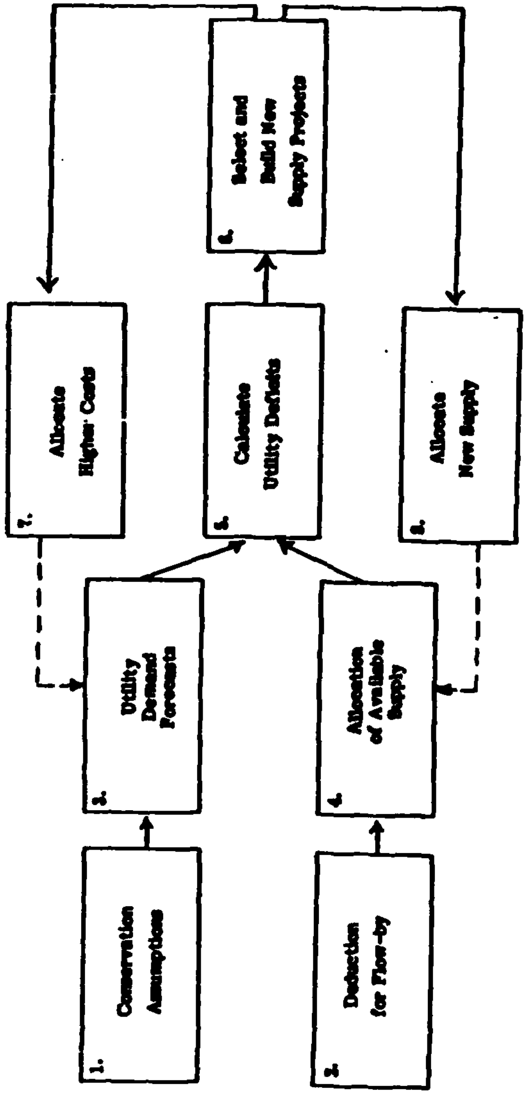


Exhibit III-22: SCENARIO DEVELOPMENT PROCESS

c. The Role of Pricing in Scenario Development

Water supply scenarios are important planning tools used to determine future capacity requirements. They are, however, something less than completely deterministic. A scenario development process such as that described above contains a considerable amount of decision-making that is, in fact, rather arbitrary. This is particularly evident to an economist because pricing is a mechanism that, in theory, can accomplish all the steps shown in Exhibit III-22 with much greater precision.

The feedback loops in Exhibit III-22 (dashed lines) illustrate the inherently circular and iterative nature of the scenario development process. An initial allocation of water and an initial demand forecast determine the need to construct the first increment of new capacity. Ideally, the cost and water allocations of the two feedback loops should then determine the next supply/demand starting point. The total process should then repeat until the planning horizon (in this case, the year 2030) has been reached. These feedback loops were of central concern in developing scenarios for this pricing study because these two feedback loops essentially represent the role of pricing. They are discussed in further detail below.

(1) Forecasting Demand

The Draft Progress Report scenario development methodology began, like most conventional water supply planning, with a single demand forecast leading all the way to the year 2030. The effect of the feedback loop indicated by the dashed line between steps 7 and 3 in Exhibit III-22 was simulated by the conservation assumptions of step 1. In Conservation Scenario No. 3, the preferred case, it was assumed that the degree of conservation would increase gradually over time in response to higher costs and prices. By the year 2030 conservation was assumed to have reduced the level of the demand forecast by 10 percent which amounts to about 100 MGD for the Potomac dependent utilities. The scenario represents a level of conservation believed most likely with present rate structures and public education programs.

This use of a single demand forecast in water supply planning necessarily entails some error as the actual iterative feedback mechanism driven by pricing policy is likely to be a very dynamic process. Short of using an iterative planning model to simulate the response of demand to price changes, the Draft Progress Report procedure represents a reasonable, though unrefined, procedure.

The use of a single demand forecast presented the study team with somewhat of a tautological paradox; how do you forecast the effect of pricing on demand when the price is based on a cost forecast which is in turn based on a demand forecast? If analysis shows that such a price does have an effect on demand, then the initial demand forecast must be in error. In theory, the price mechanism solves this problem simultaneously and continuously; there is no initial demand forecast in the operation of markets in the real world. In the less-real world of planning and forecasting, the best solution would be to design an iterative forecasting model to simulate this process. In the absence of such a model, Conservation Scenario No. 3 of the Draft Progress Report was adopted for use as it reflects at least some attempt to simulate this process.

(2) Scheduling New Capacity Increments

A single demand forecast like that of Conservation Scenario No. 3 can be used to project the "deficit" curves for individual utilities and for the entire region over the total planning period. Such curves are presented in Exhibits III-23 and III-24. These curves show when the forecasted growth in demand may generate deficiencies in supply. The degree of shortfall may also be measured directly from the diagram. It is therefore a straightforward matter to use such curves to schedule and size new increments of capacity. The result is a supply scenario which can then form the basis of a cost forecast.

The curves in Exhibits III-23 and III-24 were developed for this study using the demand forecast of Conservation Scenario No. 3. This demand forecast was adjusted, however, to produce a number of cases representing environmental flow-by at levels of zero, 100 MGD, 300 MGD, and 600 MGD. These cases accomodate uncertainty over the correct level of flow-by and also provide sensitivity analysis.

Using these demand forecasts for different levels of flow-by, supply projects were scheduled by graphic analysis to form water supply scenarios. The sizing of the project capacities was based on preliminary studies which indicated the benefits of supply management in terms of how long the Bloomington and Little Seneca projects could be expected to meet the Conservation Scenario No. 3 demand forecasts. As shown on the diagrams, only Bloomington is required for the zero flow-by case. Bloomington and Little Seneca are both required for 100 and 200 MGD levels of flow-by. Very expensive pipeline interconnection projects are shown to be needed for flow-by levels of 300 MGD

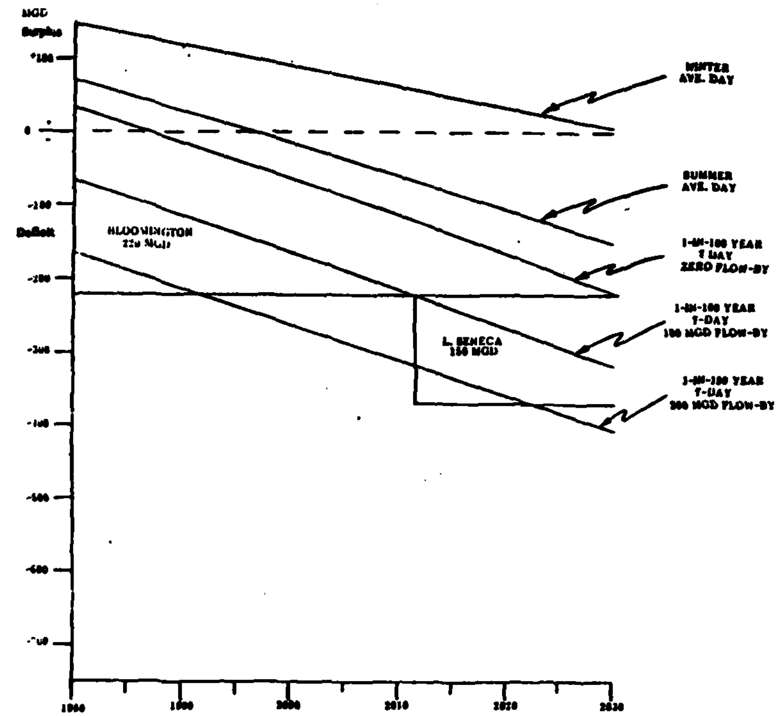


Exhibit III-23: SCENARIOS FOR ZERO, 100 MGD FLOW-BY AND 200 MGD FLOW-BY

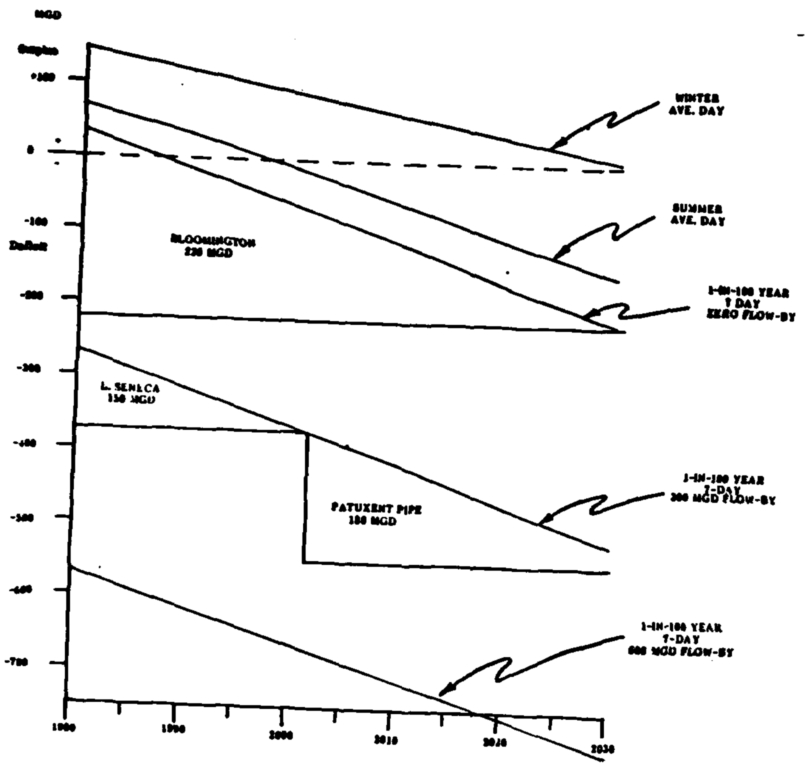


Exhibit III-24: SCENARIOS FOR 300 MGD FLOW-BY AND 600 MGD FLOW-BY

and above. From the graphic scheduling of supply projects, it was then possible to determine the effective project capacities under supply management by reading amounts from the left-hand axis.

(3) Developing Cost Forecasts

Once the new water supply projects were assigned their places in the schedules of the scenario, cost forecasts were developed in a straightforward fashion. Cost data for each project were taken from the Draft Progress Report. Costs were assigned to categories as defined in Section III.B1. Capital costs were adjusted for inflation and converted to annual costs also as described earlier in Section III.B1. The resulting regional long-run marginal cost curves are presented in Exhibit III-25.

The allocation of the water and the costs of new facilities indicated by the feedback steps in the scenario development process (Exhibit III-22) were undertaken by very different means than those applied in the Draft Progress Report. In this pricing study, it was necessary that all utilities in the region would pay the same marginal cost for new capacity, represented by the long-run marginal cost curves in Exhibit III-25. In the Draft Progress Report there were numerous factors which prevented such an even allocation, as discussed in Section II.D2.

In order to assure that all utilities in the region would pay the same marginal cost for new capacity, a hypothetical regional authority was assumed. This regional authority was assumed to operate like "one-big-utility." It would build new capacity and then impose commodity and peak period surcharges on all utility bills in the region equivalent to the appropriate portions of the long-run marginal cost. This hypothetical *institutional arrangement is equivalent, for theoretical purposes, to the cost-sharing* arrangements that have been recently proposed as part of a revised Low Flow Allocation Agreement (LFAA).

The proposed revisions to the LFAA would base utility shares of regional capacity costs on utility shares of the regional growth in peak demand. This formula can also assure that all utilities face the same marginal cost curve. This proper theoretical allocation of regional capacity costs also assures a fair allocation of the cost of setting some capacity aside for environmental flow-by. Under this type of arrangement, no one must bear an unfair share of the internalized cost of this environmental externality.

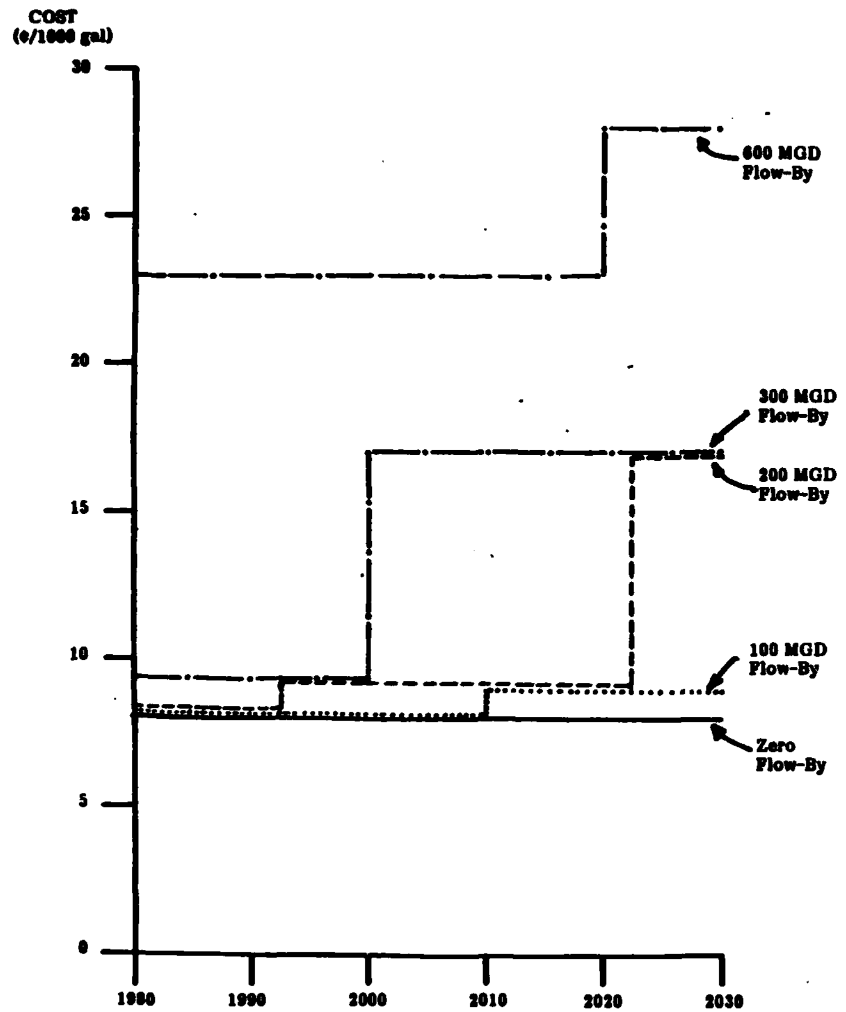


Exhibit III-25: REGIONAL LONG RUN MARGINAL COST FORECASTS FOR DIFFERENT LEVELS OF FLOW-BY

Because the level of flow-by required and the benefits and costs of providing flow-by are still somewhat at issue, the results in Exhibit III-25 are of considerable interest. Notably, there is little difference in cost, over most of the planning period, between the zero, 100 MGD, and 200 MGD levels of flow-by.

C. RATE CALCULATIONS

Certain calculations are required in order to convert long-run and short-run marginal cost estimates into peak and offpeak marginal charges. The desired marginal rates are calculated as follows:

- Offpeak Rate = Commodity Charge = Short-Run Marginal Costs + Offpeak Portion of Long-Run Marginal Costs

- Peak Rate = Commodity Charge + Peak Surcharge

  where, Peak Surcharge = Peak Portion of Long-Run Marginal Costs

In essence, all that is required is a differentiation between peak and offpeak components of long-run marginal costs. This is achieved in straightforward fashion using data on the seasonal patterns of demand. Before describing this process, however, it is necessary to review two adjustments that were made to the long-run marginal cost estimates to correct for some "real-world" differences between the concepts of marginal cost and avoidable cost. The remainder of this section therefore consists of three subparts:

- Utilization Adjustment to LRMC
- Billing Adjustment to LRMC
- Peak Responsibility for LRMC

1. Utilization Adjustment to LRMC

The long-run marginal costs of additions to water and sewer capacity were calculated by dividing the annual payment by 365 times the additional peak day capacity. This gives the cost per unit of additional capacity. However, some portion of the capacity of a new plant is planned to serve future growth in demand. So, during the first several years after construction, that portion of the capacity reserved for the future is idle. The idle portion could be used for peak demand during this period, but for the most part it is not. Therefore, it is not appropriate to charge the cost of this idle capacity to peak users. Instead, it must simply be regarded as wasted capacity which increases the

effective long-run marginal cost. In other words, less capacity is actually being purchased at the same cost.

To adjust the long-run marginal cost estimates for this effect, it was estimated that the maximum amount of the lifetime capacity of a plant (peak day capacity times 365 times economic life in years) to be idled would be 25 percent. This means that the long-run marginal cost should be recalculated by dividing the annual payment by 365 times three quarters of the peak day capacity. This yields an estimate of the long-run marginal cost which is one-third larger. Because utilities cannot charge anyone directly for capacity that is not used, they must make up their expenses by charging more for the capacity which is in use.

2. Billing Adjustment to LRMC

Another adjustment thought to be required in order to steer true to the concept of avoidable cost pricing has to do with correcting for imperfections in the relationship of the billing cycle to peak demand events.

As further elaborated in the next section, the portion of long-run marginal cost attributable to peak period demand is that associated with the portion of capacity which is only used during the peak period. Moreover, the most expensive increments of capacity should be used to calculate this peak responsibility.

As detailed in subsection 3 below, review of a 10-year data series of daily demands for the major Potomac dependent utilities produced an estimate of 15 percent for the percentage of total capacity that is attributable exclusively to peak demands. This 15 percent was reduced to 10 percent, however, to take account of the fact that the avoidable cost charged must represent an average over the entire peak quarter. The 15 percent is caused by a few sharp peaks on a very few days. In selecting an average charge over the entire quarter, it is reasoned that it is better to undercharge a very few peak customers than to overcharge the majority of peak customers.

The proper procedure for finding the long-run marginal cost attributable to the 10 percent of capacity would be to form a capacity-weighted average of the costs of the most expensive plants until their output equals 10 percent of the total. In the case of

the Potomac dependent utilities, however, the total expansion over the planning period exceeds a 10 percent capacity increase as do many individual projects. Therefore, only the most expensive new capacity (usually the newest) was used for an estimate of the long-run marginal cost attributable to the peak. This produces conservatively high peak charges.

3. Peak Responsibility for LRMC

a. Long-Run Marginal Cost of Water Service

The portion of long-run marginal costs attributable to peak demand for water is the portion associated with capacity that is used only during the peak period. A first step, therefore in calculation of a peak charge is the determination of the peak demand period. Exhibit III-26 presents a bar chart summarizing 10 years of monthly demand data for WSSC which is characteristic of seasonal patterns in the region. It is shown that the months of June, July, August, and September constitute a definite peak period in which even the average day demands exceed the peak day demands of every other month.

One way to proceed would be to develop a peak charge for this four month period. This would be a change from the existing quarterly billing practice of most utilities, but billing in thirds may actually save some billing costs. The alternatives are to have two peak quarters which would spread costs out and dilute effectiveness; or, to have a single peak quarter which would require dropping one of the four months in the data. This latter option was selected. The month of June can be dropped, despite its high demands, because the lowest flows and therefore, highest deficits (the basis for capacity planning) occur in July, August, and September.

To yield the highest conceivable peak quarter charge, regional demand data for 1974 (the most extreme of the last 10 years) were used. These data are shown in Exhibit III-27 which illustrates that the peak quarter required an extra 15 percent of capacity that was not used in any other quarter of the year. This is the portion of long-run marginal cost that should be charged to the peak quarter. As detailed in subsection 2, above, however, this was reduced to 10 percent to adjust for the fact that quarterly billing cannot be sufficiently precise to capture the true peak day.

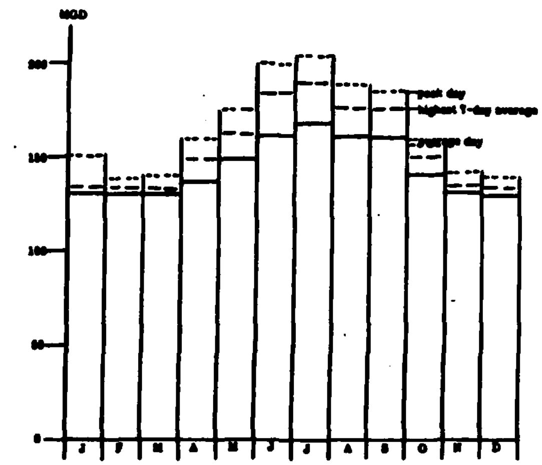


Exhibit III-26: TEN-YEAR MONTHLY PATTERN OF DEMAND VARIATION (WSSC 1970-1979)

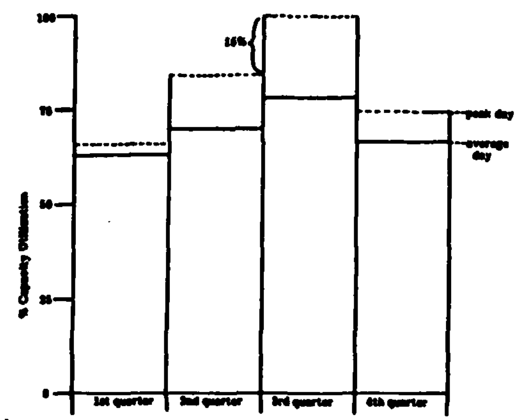


Exhibit III-27: 1974 QUARTERLY PATTERN OF CAPACITY UTILIZATION (For all Potomac Users)

The peak surcharge is calculated by simply multiplying the long-run marginal cost of the 10 percent used only in the peak quarter by four. The commodity charge, the charge for capacity used on a year-round basis, is simply equal to the long-run marginal cost.

b. Long-Run Marginal Cost of Sewer Service

Many studies of water pricing do not take account of sewer prices. This is an important item to include, however, because consumers are often billed for sewer service according to metered water use and view the total price for the two as a single commodity. Unfortunately, sewer service is characterized by a different peak period than water -- in fact, almost exactly opposite. The peak sewer flows occur during the eight month period extending from October through May, with the exception of an occasional June or September peak due to a hurricane.

The key factor in determining peak sewer flows, however, is not demand but rather infiltration of groundwater into the sewer system during these months. Considering the fact that the peak period is not caused by peak demand, it may seem unfair to impose a peak charge on users. But this must be done because there is an opportunity cost to society in peak period use. The extra capacity needed for peak period use could be reduced by reductions in peak flows. In this sense, reduction of peak use is of equal value to society as reduction in infiltration.

Since the extra capacity to serve the peak period is only used during two-thirds of the year, the peak charge is calculated by multiplying the long-run marginal cost by one and a half. This can be seen as follows:

$$\text{LRMC} = \frac{\text{Annual Payment}}{\text{Daily Capacity x 365}}$$

$$\text{Peak Charge} = \frac{\text{Annual Payment}}{\text{(Daily Capacity) x (365) (2/3)}} = (3/2)\ (\text{LRMC})$$

The commodity charge for sewer capacity used year-round is simply the long-run marginal cost.

Several researchers have argued against the idea of a peak sewer charge on practical grounds. According to one argument, it is the long-run elasticity of demand that must be the target of sewer pricing because changes in demand (such as conservation retrofit) entail a major adjustment in demand behavior that must be induced and reinforced by sustained higher prices. It is further contended that this effect on demand can be achieved by charging for sewer capacity costs on an average annual basis (i.e., in the commodity charge). This average annual approach increases the year-round commodity charge and therefore, also increases the marginal summer rate for water because the peak surcharge is added to a higher commodity charge.

The effect of this average annual approach is to increase the sewer commodity charge to a level of two times the long-run marginal cost, derived as follows:

$$\frac{\text{Annual Payment}}{\text{(1/2) (Daily Capacity) x 365}} = (2)\ (\text{LRMC})$$

The capacity is multiplied by half because infiltration which accounts for roughly half of the hydraulic capacity required is non-revenue producing flow. As a result of eliminating the peak sewer charge, the base flow capacity must be charged all of the plant costs. This rate structure alternative is a deviation from economic efficiency but it may make the concept of a summer peak surcharge more viable. Limited testing of the concept using the empirical data developed in this study showed that the resulting summer quarter rate would be equal to the existing average cost rate for some utilities in the 100 MGD flow-by scenarios. This would not occur before the year 2000, however.

D. ELASTICITY OF DEMAND

As noted in several previous places in this report, the original plan for this study was based on the expectation that theoretically optimal pricing would produce water rates higher than those charged presently. Accordingly, it was believed that an important part of the research would have to be directed at the development of an estimate of the elasticity of demand. The elasticity of demand is the economists' measure of the responsiveness of the demand for a commodity to a change in its price. It is necessary to have an estimate of the elasticity in order to predict the reduction in demand that would be produced by a change to a higher price. Study results contradicted initial expectations, however, and the elasticity of demand became unimportant by comparison to the finding that the marginal cost peak period price was below most current rates. Considerable attention had been given to the subject of elasticity up until that point and several resulting observations are worthy of note.

First, it was suspected at the outset that developing a thoroughly researched estimate of elasticity for use in this study would be very difficult due to the breadth of the overall study. Estimating the elasticity of demand for water, especially that of peak demand, is greatly complicated by the variability of climatic events. From the start, it was intended to rely heavily upon the available literature for an estimate of elasticity. The results of these investigations are reported in a technical footnote in Appendix A.

Despite the difficulty of developing an original estimate of elasticity, the study team nonetheless attempted to collect the needed data from the utilities, hoping perhaps to get lucky. These efforts yielded an interesting finding; the utilities do not have a good data base from which to develop estimates of elasticity. This highlights an important area of research need.

Utilities such as the Washington Suburban Sanitary Commission (WSSC) and the Fairfax County Water Authority (FCWA) which are so heavily engaged in the pursuit of innovation in rate-setting policy had the best available information. They both had extensive records tracking the progress of their rate-structure innovations. The data they collect, however, is not relevant to the needs of the economist. WSSC had extensive records showing shifts in the number of customers in each rate block in different demand periods and in dry vs. wet years. Similarly, FCWA had extensive data

showing changes in the number of customers having to pay the peak period surcharge. Neither utility, however, had the data needed to directly relate a change in price to a change in the quantity demanded by a sample of individual consumers. Regardless of the immediate applicability of theoretically optimal pricing policies, utilities should be taking advantage of current rate structure experiments to develop estimates of elasticity. The fruits of such research will be to make further improvements in pricing much easier to recognize as opportunities present themselves.

THE ROLE OF PRICING IN WATER SUPPLY PLANNING FOR THE METROPOLITAN WASHINGTON AREA

VOLUME II

Submitted to:

U.S. ARMY CORPS OF ENGINEERS
Baltimore District

June, 1982

Submitted by:

JACK FAUCETT ASSOCIATES, INC.
5454 Wisconsin Avenue
Chevy Chase, Maryland 20815

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF EXHIBITS (Continued)

LIST OF EXHIBITS

LIST OF EXHIBITS

LIST OF EXHIBITS

APPENDIX A

TECHNICAL FOOTNOTES

1. REAL RATE OF INTEREST

The real carrying cost of money is the interest rate that should be applied to the capital investment when it is expressed in constant dollars -- this cost is necessary for calculating the annualized cost of an investment in water utilities. Nominal rate of interest includes inflation as well as risk and time preference. If inflation were ten percent per year, the nominal rate would be 1.1 (1.03) = 1.133 compared to the real rate of 1.03. Time preference factor is the relative value one year earlier; a two percent time preference means the value this year is two percent greater than the value next year, for whatever reason the lenders might have. The risk factor accounts for the difference in utility when there is variation. For example, a payoff with a .5 probability of $1 and a .5 probability of $3 next year, may have less value than a $2 payoff with probability of 1.0. Presumably, this would mean that lenders perceive a greater potential loss in the $1 payoff than the potential gain in the $3 payoff. However, the only justification of a risk factor is that lenders simply indicate a discount for risk; analysts must accept the lenders preference.

This study used a three percent annual real rate of interest to represent both risk (other than inflation) and the time preference (for money that is invested in water utilities). Our three percent is in the middle of estimates that range from .5 to 8 percent (9)(10)(11)(12)(13).

A report to Congress on waterway development used and defended an approximate three percent real rate of return (14); the same report also explained why the real rate is important in evaluation of projects.

The real carrying cost cannot, for example, be determined by subtracting the typical ten percent borrowing rate for utilities from the current inflation rate of 12-18 percent. Rather, the calculation depends on the lender's and borrower's expectation of the inflation rate over the life of a bond, generally 20-30 years. There is no unique way to determine the lender expectation —the expectation which determines the opportunity cost of money tied up in water utility bonds.

It seems that many lenders in the early 1950's might have viewed the inflation rate as nearly constant and small; therefore, the 2-4 percent real rate of interest on long-term bonds in that period is a good measure of the estimated carrying cost of money (9); it is an estimate that can be used for this study. Recent authors have also suggested similar low rates for the real rate of interest (10)(11); e.g. a Harvard University study for the Federal government suggested a three percent rate for evaluation of social programs (15).

Discussions with the U.S. Department of Interior staff indicate that real interest rates as high as eight percent are being used for government projects such as oil and gas leasing agreements. Some of their justification is based on work by Ott (12) and analysis for Federal Trade Commission reports (13). However, with the frequency of years which existing water utility bond rates are less than inflation, it seems that lenders for utility bonds must require an expected nominal rate of interest that is sufficiently close to the inflation rate that actual inflation can exceed the expected rate (the expected value of inflation times the real interest rate). All things considered, there is more justification in a three percent than an eight percent real rate of interest in this report.

In FY 1981, the Water Resources Council prescribed a 7-3/8 percent carrying cost on real dollars (16). They required the Corps of Engineers (COE) to apply a 7-3/8 percent interest rate after expressing costs and benefits in constant dollars. There is no way to compare the risk in typical COE projects with that in water utilities. A finding of this study was to show that the prescribed 7-3/8 percent rate for water projects exceeds the real rate of interest -- the opportunity cost which appears to be approximately three percent per year. Since the borrowing rate for water utilities has been close to or even less than the inflation rate in recent years, it seems that three percent is better than the COE 7-3/8 percent for purposes of these projects.

In summary, it is clear that the negative and zero differences between interest rates and inflation in recent years is too low as an acceptable carrying cost of capital over the 1980-2030 period. On the other hand, estimates of 8-10 percent derived from the 1950-60 decades seem too high. The suggested three percent to include both carrying cost and risk seems the best that can be derived from existing knowledge and data.

2. ELASTICITY OF DEMAND

Elasticity of demand must be estimated in order to assess the demand response to price increases. Elasticity (E_D) is a simple expression for specifying how demand will change with a price change.

E_D = percent change in demand for a one percent change in price

$$= \frac{\Delta D/D}{\Delta P/P} = \frac{\Delta D}{\Delta P} \times \frac{P}{D}$$

Where D is the demand level and P is the price level before the price change (ΔP) -- for this study, they are conditions under present pricing.

An estimate of -.25 was selected in this study. This means that for every ten percent increase in price, demand will decrease 2.5 percent. A -.25 estimate is within the range of published estimates. It is in the lower range of published estimates because the Fairfax peak-period charge and the other rate changes in the Washington area do not reveal a price elastic demand. There is no opportunity for rigorous statistical analysis because there are many factors that could have shifted demand in the few instances of rate changes and because rate effects are likely to be lagged and confused with even more factors. The -.25 is the best judgement, considering all factors.

There might be some reason to modify the estimate for use in commodity pricing and peak period pricing in some other water districts, but the same -.25 estimate was used for all analyses in this report.

The potential variation in estimates is indicated in Exhibit A-1. These estimates were selected from review of other studies and from graphical analysis of recent changes in water rates in local utilities in the Washington, D.C. Metropolitan area. There is little reason to believe that further statistical analysis will generate more accurate estimates of long-run demand elasticities. Until more years of experience with new rate structures and new rate levels are available, there just is not enough data to provide more reliable estimates than judgements like those in Exhibit A-1. In recent work, Morgan suggests a value of -.3 (17) and Carver suggests a value of -.1 to -.4 (7).

EXHIBIT A-1

POINT ESTIMATES OF ELASTICITY AND LIKELY RANGES

	Off-Season	Peak-Season
Short-Run (Range)	-.1 (-0.5 to -.3)	-.1 (-.05 to -.4)
Long-Run (Range)	-.25 (-.1 to -.4)	-.25 (-.2 to 0.4)

Some recent research shows the E_D to be -.27 to -.49 in Arizona. This does not conflict with the suggested -.25 because it is likely that demand in the arid west is more price elastic.

Young estimated E_D to be -.4 to -.6 (18)(19), but another analysis of the same data showed the E_D to be generally less than -.1 (18). Such changes in estimates as these certainly reduce confidence in available estimates. In any case, the available high estimates seem to have enough weaknesses to justify the relatively low -.25 value used in this study.

There is no obvious criticism of the relatively high -.7 estimate developed by Howe and Linaweaver (19). *Their analysis in the 1960s is quite old, and their sample was quite* small. Their use of individual user data was very good. It would be necessary to understand the conditions in this sample period in order to compare their estimate with the -.25 favored in this study.

The wide range of estimates in Exhibit A-2 shows the variation in estimates from different studies and different regions. Even after correcting for residential and commerical variation and adjusting between long-run and short-run, there is little concentration of estimates around any particular value. Sample variation is large in all studies of both short-run and long-run demand elasticity. Short-run elasticity is the demand response within, say, one year. Long-run elasticity is the eventual total response and might take several years for most of the response to occur.

The hope for reliable estimates of long-run elasticity is very small. On the one hand, cross-section data reflect more non-price differences among users within different districts than price differences, particularly with price changes exerting demand effects in nearly all periods. On the other hand, time-series data reflect a very

complex set of past price changes that are still exerting effects. The following model is an attempt to capture both short-run and long-run elasticity, but it has severe limitations for developing reliable estimates:

$$D_t = a_0 + a_1 P_t + a_2 (D_{t-1}) + a_3 X + e$$

where X can be a vector of exogenous variables. If the variables are in logarithms, the short-run elasticity is "a_1" and the long-run elasticity is $\frac{a_1}{1-a_2}$.

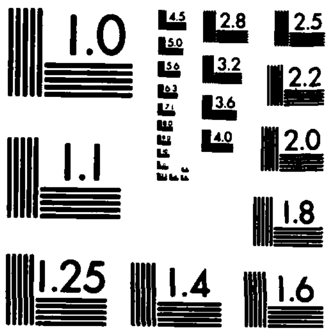
There are two severe problems in the accuracy of the long-run elasticity estimated in the above formulation. First, the standard deviation cannot be determined from least-squares estimates of coefficients "a_1" and "a_2." Second, the error in the ratio $\frac{a_1}{1-a_2}$ becomes large relative to the error in "a_1" as "a_2" approaches 1.0. Since the long-run elasticity is likely to be more than twice the short-run elasticity the latter factor is serious. When quarterly data are used, the "a" short-run elasticity is the response in the next quarter. Since consumers do not study their bill each quarter and they need time to adjust their water use, the authors judged that short-run elasticity is likely to be less than one-half the long-run elasticity.

Since Carver and Boland (22) have recently analyzed the Washington D.C. area statistics, there is little that can be gained from further statistical analysis until a few more years of data are available. A Pennsylvania State University study of conservation in WSSC (23) included statistical analysis of price effects, but researchers have explained that no reliable estimates were developed from time-series analysis. It seems clear that future statistical analysis, after more years of experience become available, should include both cross-section and time-series data. The long-run price elasticity is crucial for pricing studies, but it cannot be estimated reliably from either cross-section or time-series alone. The nature of future price increases will determine, in part, the hope for better estimation. The moisture deficit variation will also determine the richness of data. Most importantly, the more years for which data are available, the more hope for better estimation. The present data base for 1971-1980 is a good start; it includes some price increases that will probably exert demand effects for several years into the 1980s.

The analysis in this report requires the demand response in the peak-day of the peak-year to the quarterly rate. There is really no price elasticity study which focuses

AD-A134 159 METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY APPENDIX G NON-STRUCTURAL STUDIES(U) CORPS OF ENGINEERS BALTIMORE MD BALTIMORE DISTRICT SEP 83 MWA-83-P-APP-G

UNCLASSIFIED F/G 13/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

directly on this parameter. The FCWA has introduced a significant peak charge to influence the peak-day, but there is little hope of deriving an elasticity because the surcharge applies to a vague set of users. The Carver study of FCWA developed a very low estimate of about -.1, but the estimate appears to be questionable, as suggested by the author in personal communication.

Any researcher can gain some support for any demand elasticity estimate from zero to nearly -1.0. It is believed, however, that the -.25 selected in this study is probably much closer to the likely demand response than is a higher elasticity. There are even some observations that suggest demand response is much lower; near zero for typical price changes.

It is not clear that long-run price elasticity is definitely greater than any of the observed short-run price elasticities. With the considerable publicity about price increases and conservation, the initial (short-run) user response might exceed the demand flexibility and price response in the long-run. Since there is no substitute for water in virtually any use, there is little support for the hypothesis that the long-run demand is price elastic.

Price elasticity for a daily or hourly peak-charge could be considerably larger than the -.25 suggested for the quarterly charge, because there is easier substitution from one day to another. Most of the potential demand response to price is in shifting water use to another hour or another day because the decision and carrythrough on substitution is easy. Unfortunately, hourly and daily metering that is required for shifting daily peaks is not considered economically feasible.

Exhibit A-2:

PUBLISHED ESTIMATES OF ELASTICITIES OF DEMAND FOR WATER

Investigator	Year	Data	Price Elasticity Residential	Price Elasticity Comm/Ind.	Income Elasticity
Metcalf	1926	29 waterworks systems, cross-sectional	-0.65[a/]		
Gottlieb	1943-49	12 Illinois cities	-0.27[a/]		
	1952	68 Kansas cities	-1.02[a/]		
	1952	19 Kansas cities	-1.24[a/]		
	1957	94 Kansas cities	-0.69[b/]		
	1957	24 Kansas cities	-0.66[a/]		
	1960	24 Kansas cities	-0.66[a/]		
	1963	Kansas cross-sectional	-0.66 to -1.24[a/]		0.28 to 0.58[a/]
Larson and Hudson, Jr.	1951	15 Illinois communities, cross-sectional			0.70[a/]
Hanson and Hudson, Jr.	1956	8 Illinois communities, cross-sectional			0.55[a/]
Seidel and Baumann	1957	American cities, cross-sectional:			
		@ .15/1,000 gal.	-1.0[a/]		
		@ .45/1,000 gal.	-0.12[a/]		
Fourt	1958	34 American cities cross-sectional	-0.39[b/]		0.28[b/]
Renshaw	1958	38 water service systems, cross-sectional	-0.45[a/]		
Headley	1963	S.F. - Oakland 1950-59 time series			0.00 to 0.40[b/]
Heaver and Winter	1963	Ontario cities	-0.254[b/]		
Hedges and Moore	1963	Northern California irrigation		-0.10[b/]	
Milliman	1963	Speculation	-0.3 to -0.4[b/]		
Wong, et al.	1963	Northeastern Illinois, cross-sectional	-0.1[illegible] to -0.72[b/]		
Howe and Linaweaver	1963-65	21 residential sprinkling	-1.12[b/]		0.682[b/]
	1963-65	10 public sewers, west	-0.7[illegible][b/]		0.429[b/]
		11 public sewers, east	[illegible]		1.45[b/]
	1963-65	21 residential maximum day sprinkling	-0.6[illegible][b/]		
		10 public sewers, west	-0.388[b/]		0.438[b/]
		11 public sewers, east	-1.2[illegible][b/]		0.031[b/]
	1967	35 study areas, cross-sectional	-0.21 to -0.23[b/]		0.31 to 0.37[b/]
Gardner and Schick	1964	43 northern Utah water systems, cross-sectional	-0.77[c/]		
Flack	1965	54 western cities, cross-sectional			
		@ .15/1,000 gal.	-1.0[c/]		
		@ .25/1,000 gal.	-0.61[c/]		
		@ .35/1,000 gal.	-0.32[c/]		
		@ .45/1,000 gal.	-0.12[c/]		

Exhibit A-2: (cont'd)

PUBLISHED ESTIMATES OF ELASTICITIES OF DEMAND FOR WATER

Investigator	Year	Data	Price Elasticity Residential	Price Elasticity Comm/Ind.	Income Elasticity
		all cities			
		@ .15/1,000 gal.	-0.29[a]		
		@ .25/1,000 gal.	-0.45[a]		
		@ .35/1,000 gal.	-0.49[a]		
		@ .45/1,000 gal.	-0.63[a]		
		@ .55/1,000 gal.	-0.41[a]		
		@ .65/1,000 gal.	-0.20[a]		
Ware and North	1966	634 Georgia residences	-0.07[a]		
Bain, Caves and Margolis	1966	41 northern California cities irrigation	-1.10[a]	-0.94[a]	
	1966	43 California cities, cross-sectional	-1.000[a]		
Conley	1967	24 southern California communities, cross-sectional	-0.33 to -1.02[a]		
Bruner	1969	Phoenix	-0.3[a]		0.8[a]
Turnovsky	1969	19 Massachusetts towns, cross-sectional	-0.05 to -0.40[a]	-0.47 to -0.86[a]	
Burns, et al.	1970	stratified two price comparison	-0.28 to -0.26[a] in-house; -0.27 to -0.83[a] sprinkling		0.230 to 0.246 in-house; 0.257 to 0.31 sprinkling
Grima	1970	91 observations, cross-sectional	-0.93[a]		0.56[a]
	1972	Ontario cities, winter / summer	-0.75[a] / -1.07[a]		
Wong	1976	Chicago, 1951-61 time series	-0.02 to -0.28[b]		0.20 to 0.26[b]
		four community size groups, cross-sectional	-0.26 to -0.82[b]		0.48 to 1.03[b]
Ridge, R.	1972	cross-sectional, industrial		-0.3 malt liquor[c]; -0.6 fluid milk processing[c]	
Hellman and Primeaux	1973	Mississippi cities	-0.20 to -0.48[f]		0.24 to 0.30[f]
Young, R.A.	1973	Tucson, time series 1941-1971	-0.20[f]		
DeRooy	1974	New Jersey, chemical, cross-sectional		-0.89 cooling[h]; -0.74 processing[h]; -0.74 steam-generation[h]	
Morgan	1974	Santa Barbara, California	-0.49[i]		
Grunewald, et al.	1975	190 rural Kentucky, cross-sectional	-0.92[i]		
Hagarty and McCoy	1975	Blacksburg, Virginia 2 year time series	-0.50 to -1.41[k]		

Exhibit A-2: (cont'd)

PUBLISHED ESTIMATES OF ELASTICITIES OF DEMAND FOR WATER

Investigator	Year	Data	Price Elasticity Residential	Price Elasticity Comm/Ind.	Income Elasticity
Pope, et al.	1975	4 South Carolina cities, 2 and 3 year time series	0.00 to -0.31		0.004 to 0.612
Boland	1977	Washington, D.C. 1947-75 time series	-0.4 to -0.6		
Camp, R.C.	1978	228 Mississippi households, cross-sectional	-0.24 to -0.31		
Carver	1978	Fairfax County, Virginia 4 year time series of an innovative rate structure	-0.013 to -0.17 1st year; -0.02 to -0.04 2nd year		
	1980	Washington, D.C. 8 year time series, cross-sectional	-0.1, short-run; -0.02 to -0.78, non-seasonal		
Lynne, et al.	1978	Miami, Florida cross-sectional		-1.33 dept stores; -0.89 groc stores; -0.14 to -0.38 hotels, eating, & drinking	
Foster and Beattie	1979	Great Bend, Kansas; Calumet, Illinois; Colorado Springs, Colorado; Huntsville, Alabama	-0.67; -0.27; -0.76; -0.44		
Billings and Agthe	1980	Tucson, Arizona 1974-1977	-0.56 to -0.66		
Agthe and Billings	1980	Tucson, Arizona 1924-1977	-0.17 to 0.358, short-run; -0.266 to -0.786, long-run		
Undated					
Clark		midwest SMSA	-0.6		
Leone, Glen and Lin		cross-sectional, industrial	-0.3 to -0.4 paper; -0.4 to -0.7 chemical; -0.4 to -0.5 petroleum; -0.7 to -1.1 steel		

a/ Reference (20)
b/ Reference (20)
c/ Reference (20)
d/ Reference (9)
e/ Reference (9)
f/ Reference (21)
g/ Reference (21)
h/ Reference (21)
i/ Reference (21)
j/ Reference (21)
k/ Reference (21)

APPENDIX B

EXCERPTS FROM ENGINEERING SUBCONTRACTOR'S REPORT

Much of the data development work for this study was performed by an engineering subcontractor, Energetics, Inc. of Columbia, Maryland. Excerpts of their report are included in this appendix.

FINAL DRAFT REPORT

Current and Projected Cost Estimates for Water Supply and Wastewater Disposal in the Metropolitan Washington Area

April 1981

Prepared by:

ENERGETICS, INCORPORATED
2000 Century Plaza
Columbia, Maryland 21044

Prepared for:

Jack Faucett Associates, Incorporated
5454 Wisconsin Avenue
Suite 1100
Chevy Chase, Maryland 20015

Department of Army Contract No. DACW 31-80
Subcontract No. JFA-277

INTRODUCTION

This report presents current and projected cost estimates for providing potable water and wastewater disposal service to the Metropolitan Washington Area (MWA) and the methodology used and assumptions made to develop those cost estimates. Methodology and assumptions are presented first and are followed by the estimates obtained. Also presented are sample calculations and summary descriptions of the major water supply and wastewater disposal systems in the MWA.

Included in the MWA are Montgomery, Prince Georges, and Charles Counties in Maryland; Fairfax, Arlington, Prince William, and Loundon Counties in Virginia; and the District of Columbia. Cost estimates were made for the major political jurisdictions located primarily within the core of the MWA and for several smaller jurisdictions located in the outlying areas of the MWA. Table 1 lists those jurisdictions for which cost estimates were developed.

Water and sewer service functions are provided to the jurisdictional entities within the MWA by numerous utility agencies. Furthermore, numerous finished water and sewer interconnections between utilities exist, and jurisdictions are often served by more than one utility agency for the same service. Table 2 presents the names and functions of the principal operating agencies serving the major political jurisdictions in the MWA. A schematic of water supply and wastewater disposal identifying the sources of raw water, water suppliers, water treatment plants and wastewater treatment plants serving the major political jurisdictions and several of the outlying jurisdictions is shown in Figure 1. An overview of water and sewer service in the MWA and summary descriptions of the water and sewerage systems maintained by the major utility agencies in the region are presented in Appendix A.

Cost information developed in this report was obtained from the following sources:

1. Literature including utility budgets and annual reports, previous cost studies by utilities or others, literature obtained from the U.S. Army Corps of Engineers, and cost estimating manuals.

2. Telephone interviews with utility and EPA personnel, and, where information was found to be incomplete or lacking,

3. best engineering judgment.

A complete list of utility and EPA personnel contacted, utility specific references, and general references are presented in the Acknowledgements and References sections.

TABLE 1. JURISDICTIONS FOR WHICH COST ESTIMATES WERE MADE

MAJOR AREAS

District of Columbia

Maryland

- Montgomery County
- Prince Georges County
- City of Rockville

Virginia

- Arlington County
- Fairfax County
- City of Falls Church
- City of Alexandria
- Fairfax City
- Town of Vienna

OUTLYING AREAS

Charles County, Maryland

- Charles County Sanitary Commission
- Town of La Plata
- Town of Indian Head

Prince Georges County, Maryland

- City of Bowie

Prince William County, Virginia

- Dale City
- Occoquan/Woodbridge-Dumfries/Triangle Sanitary District
- City of Manassas
- City of Manassas Park
- Greater Manassas Sanitary District
- Town of Quantico

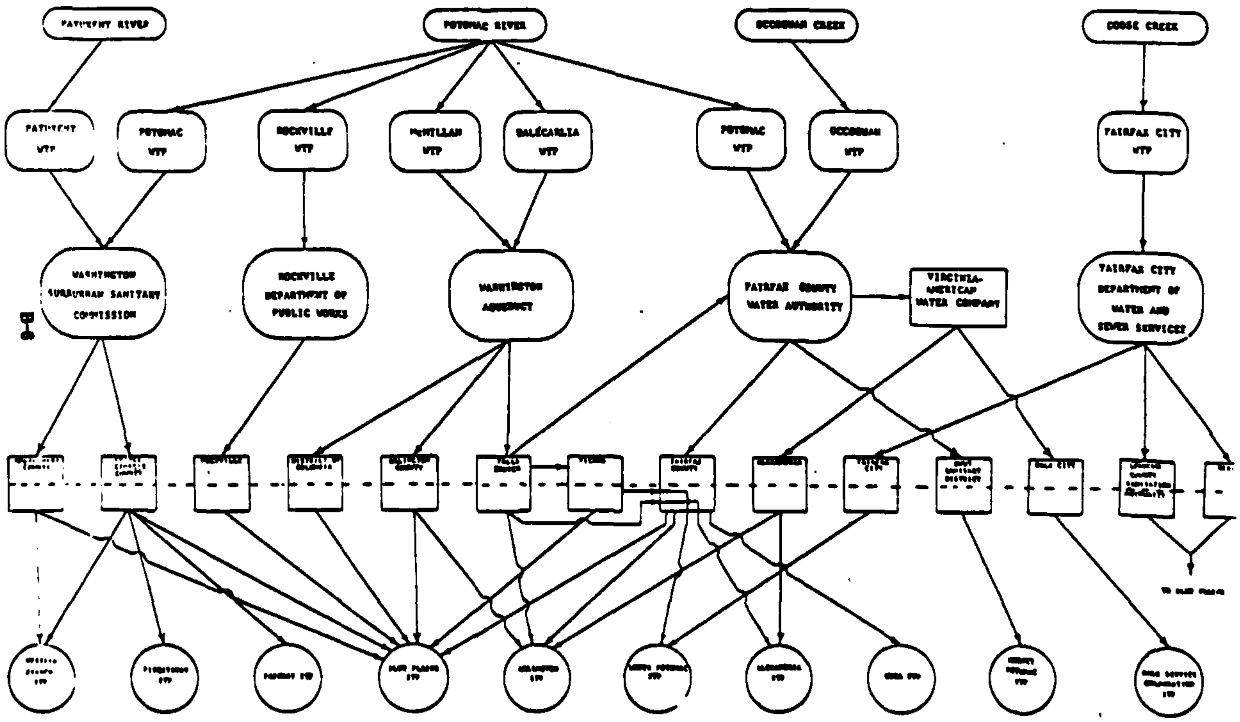
Loundon County, Virginia

- Loundon County Sanitation Authority
- Town of Herndon
- Town of Leesburg

TABLE 2. PRINCIPAL OPERATING AGENCIES SERVING THE MAJOR POLITICAL JURISDICTIONS IN THE MWA

Jurisdiction	Water Source Development	Water Treatment	Water Distribution	Wastewater Collection	Wastewater Treatment
Montgomery and Prince Georges Counties, MD	Washington Surburban Sanitary Commission (WSSC)	WSSC	WSSC	WSSC	WSSC/D.C. Dept. of Environmenta Services(D.C.DE
Rockville	Rockville Dept. of Public Works (DPW)	Rockville DPW	Rockville DPW	Rockville DPW/ WSSC	D.C. DES
District of Columbia	Washington Aqueduct Division (WAD)	WAD	D.C. DES	D.C. DES	D.C. DES
Arlington County	WAD	WAD	Arlington County DPW	Arlington Co. DPW	Arlington Co. DPW/D.C. DES
Falls Church	WAD	WAD	Falls Church	Falls Church DPW	Arlington Co. DPW/Fairfax Co. DPW
Vienna	WAD	WAD	Vienna DPW	Vienna DPW/ D.C. DES	D.C. DES/ Fairfax Co. DPW
Fairfax County	Fairfax County Water Authority (FCWA)	FCWA	FCWA	Fairfax Co. DPW	Fairfax County DPW
Alexandria	FCWA	FCWA	Virginia-American Water Company	Alexandria Dept. of Trans. & Environ. Services/Alexandria Sanit. Authority	Alexandria San. Authority/ Arlington Co. DPW
Fairfax City	Fairfax City Dept. of Water & Sewer Services	Fairfax City DWSS	Fairfax City DWSS	Fairfax City DWSS	Fairfax City DWSS

FIGURE 1. SCHEMATIC OF WATER SUPPLY AND WASTEWATER DISPOSAL IN THE MWA



COST CATEGORIES

The cost estimates developed for the jurisdictions in the MWA were for use in evaluating alternative pricing strategies. Functional cost categories, specified as a part of those pricing strategies, determined the manner in which the cost data were classified.

Twenty functional cost categories relating to particular aspects of water supply and wastewater disposal were specified. These twenty categories were grouped under three cost headings: short-run variable costs, long-run variable costs, and fixed costs. Short-run variable costs are those costs which vary in the short-run, and were assumed to be equivalent to those costs which vary with flow through the water or sewer system. Long-run variable costs are those costs which vary according to capacity of the water or sewerage system. Fixed costs are those costs generally determined only by the number of customers served at a particular time and which do not vary with flow or capacity added to the system. Table 3 lists and briefly describes the cost categories used.

Furthermore, it was specified that two overall types of costs be determined: marginal or incremental-pricing costs and average or revenue-pricing costs. Marginal costs represent the costs associated with the next unit of flow or capacity, while average costs represent the typical costs associated with all the flow or capacity.

All water-related costs are expressed on a cents per thousand gallons of revenue producing water and all sewer-related costs are expressed on a cents per thousand gallons of wastewater flow, unless otherwise noted. Unit costs were calculated from annual cost figures and annual amounts of water sold or wastewater flow.

METHODOLOGY FOR ESTIMATING CURRENT AVERAGE COSTS

The initial step in the development of the cost information was the determination of the current average costs of providing water and sewerage services to existing customers in the MWA. Current costs were developed from 1979-1982 data. Estimates of the costs associated with facilities currently under construction were included as current costs.

Review of accounting systems and cost data maintained by area utilities yielded an awareness of differences in terminology and cost category designation and, in some cases, lacking information. To overcome these difficulties, the following approach was taken to estimate current costs and to assign those costs to the applicable category:

Available utility cost data was first reviewed, and overall costs were segregated into administrative or support service costs, operation and maintenance costs, and capital costs. These three cost groupings were then further classified into one or more of the twenty functional cost categories as described below.

TABLE 3. COST CATEGORIES

Category	Description
Water Short-Run Variable	
Water Source O&M	O&M costs associated with acquiring and delivering raw water to a treatment facility which are a function of the amount of water delivered. The sole example in this category is raw water pumping.
Water Treatment O&M	Water treatment O&M costs which are a function of the flow through the treatment plant. Examples are power and chemical costs.
Water Distribution O&M	O&M costs associated with the transportation of finished water which are a function of the amount of water transported. The sole example in this category is finished water pumping.
Water Long-Run Variable	
Water Source Capacity	Capital costs associated with water supply projects such as the costs for a new reservoir.
Water Source O&M	O&M costs associated with acquiring and delivering raw water to a treatment facility which are a function of the capacity (size) of the water supply facility. An example is the maintenance crew for a reservoir.
Water Treatment Capacity	Capital costs associated with the construction of water treatment facilities such as the costs for a new plant or plant expansion.
Water Treatment O&M	Water treatment O&M costs which are a function of the capacity of the treatment facility such as labor to staff a plant.
Water Transmission Capacity	The capital costs associated with the construction of new transmission mains.
Water Transmission O&M	Operation and maintenance costs associated with the transmission of finished water which are a function of the size of the new transmission mains such as line maintenance costs.

Category	Description
Sewer Short-Run Variable	
Wastewater Treatment O&M	Wastewater treatment O&M costs which are a function of the flow through the treatment plant. Examples are power and chemical costs.
Wastewater Collection O&M	O&M costs associated with the collection and conveyance of raw wastewater to the treatment plant which are a function of the amount of wastewater conveyed. The sole example in this category is wastewater collection pumping.
Sewer Long-Run Variable	
Wastewater Treatment Capacity	Capital costs associated with the construction of wastewater treatment plants such as the costs for new plant or plant expansion.
Wastewater Treatment O&M	Wastewater treatment O&M costs which are a function of the capacity of the treatment facility such as labor to staff a treatment plant.
Wastewater Collection Capacity	Capital costs associated with the construction of new wastewater collection mains.
Wastewater Collection O&M	O&M costs associated with the collection and conveyance of wastewater to the treatment plant which are a function of the capacity of the new collection mains. An example is line maintenance.
Fixed Costs	
Administration	Support services costs such as general administration, billing, and collecting.
Water Distribution Capacity	The capital costs associated with the existing system for the transportation of finished water.
Water Distribution O&M	O&M costs associated with the transportation of finished water which are a function of the capacity of the existing transmission and distribution system such as line maintenance.

Category	Description
Fixed Costs (continued)	
Wastewater Collection Capacity	Capital costs associated with the existing wastewater collection system.
Wastewater Collection O&M	O&M costs associated with the collection and conveyance of wastewater to the treatment facility which are a function of the capacity of the existing collection system such as line maintenance.

Administrative Cost Component

Administrative costs were considered to be entirely fixed costs. Included in the administration cost category were all costs which did not relate specifically to the production and delivery of water or the collection and disposal of wastewater. Examples of typical cost items included are billing and collecting and general administrative expenditures.

Operation and Maintenance Cost Components

Operation and maintenance costs were classified as either short-run variable costs, long-run variable costs, or fixed costs with each grouping containing one or more operation and maintenance functional cost categories. For the most part, operation and maintenance costs maintained by utilities were consistent with the functional categories used in the study. Exceptions were the breakdown of water and wastewater treatment operation and maintenance costs into a short-run variable component and a long-run variable component, and the breakdown of water distribution and wastewater collection operation and maintenance costs into fixed, short-run variable, and long-run variable components. The following approach was used to allocate costs to the applicable category:

Water and Wastewater Treatment O&M: With guidance from EPA and utility personnel, it was determined that power and chemicals are the principal cost items that are short-run variable; that is, they will vary with the flow through the water or wastewater treatment plant at any given point in time. The remaining treatment operation and maintenance cost items were considered to be long-run variable which vary with the capacity of the applicable treatment facility.

It was found that the percentage of total treatment O&M costs due to power and chemicals varies with respect to the particular treatment plant in question. Therefore, a line-by-line review of treatment plant O&M costs was conducted to determine the actual power and chemical costs. Where a detailed breakdown of treatment O&M costs were unavailable, utility estimates of the percentage of total O&M costs due to short-run variable components versus long-run variable components were used. Where neither a detailed breakdown of treatment O&M costs nor utility estimates were available, water treatment O&M costs were considered to be comprised of 50 percent short-run variable and 50 percent long-run variable components, and wastewater costs were considered to be comprised of 40 percent short-run variable and 60 percent long-run variable components. These estimates were found to represent typical conditions for water and wastewater treatment plants.

Water Distribution and Wastewater Collection O&M: In the determination of water distribution and sewage collection operation and maintenance costs, a distinction was made between O&M costs for the existing, in-place distribution or collection system and O&M costs

for future additions of major water transmission mains or sewer collector mains to the existing distribution and collection system.

Within the existing, in-place distribution or collection system, pumping costs are the only costs items which vary with the flow through the system and were thus considered short-run variable. All other costs for an in-place distribution or collection system do not vary with the flow through the system but are determined by the size of the system and were considered fixed. Where actual pumping costs were not maintained by utilities, the electrical cost component of total distribution or collection costs were assumed to be equivalent to the pumping costs.

Operation and maintenance costs for new water transmission mains and sewer collector mains were to be long-run variable costs. Estimates of those costs were obtained from estimates given in utility literature, particularly in capital improvement programs, and from estimates given by utility personnel. Where utility data were unavailable, engineering judgments were made considering the size and length of the needed transmission or sewer collector main.

Capital Cost Components

Capital cost components were classified as either long-run variable costs or fixed costs. Capital costs consist of the debt service requirements (principal plus interest) of the utility. Also included in the capital cost categories were major capital expenditures continuously made but not funded through bond issues. Depreciation was not included.

In most instances, only the total capital cost or total water and sewer system capital cost was directly obtainable in utility literature. The distribution of the total capital cost among the capital cost categories (water treatment, water distribution, wastewater treatment, and wastewater collection) was determined by one of the following methods:

1. Distributed according to estimates provided by utilities.
2. Distributed according to a review of expenditures funded by bond issues.
3. Distributed according to the percentage of depreciation due to each capital cost component.
4. Distributed according to national data on the relative percentages of total contract awards due to each capital cost component.

Furthermore, as with water distribution and sewage collection operation and maintenance costs, a distinction was made between the capital costs for the existing, in-place system and for additions of new transmission mains and major sewer collector mains. The former were considered a fixed component of cost while the latter were considered long-run variable costs as were the other capital cost components.

The allocation of water distribution and wastewater collection capital costs into a fixed component and a long-run variable component utilized are of the four methods listed above when possible. When this was not possible, one of the methods listed below was used.

1. Distributed according to historical growth trends in the system.

2. Distributed according to engineering judgment considering the size of the existing water distribution and wastewater collection systems and future growth requirements.

In a few cases, particularly for the smaller utilities, only total operating and total capital costs were available from utility literature or personnel. To distribute those costs among the major functional categories, previous cost studies (2, 6) indicating the breakdown of costs for the particular utility in question or providing average breakdowns for similar type systems were utilized.

In the situations where water is purchased from a utility agency or another jurisdiction or where wastewater collection and disposal services are purchased, the costs of providing those services were broken down into the applicable functional cost categories and allocated to the purchasing jurisdiction. Where a detailed breakdown of costs of providing water or sewerage services to a particular purchasing jurisdiction was available, it was used to allocate costs to the purchasing jurisdiction. When such a breakdown was unavailable, the applicable average costs of the utility or agency supplying the service were allocated to the purchasing jurisdiction.

METHODOLOGY FOR ESTIMATING CURRENT MARGINAL COSTS

Marginal costs represent the costs associated with the next additional unit of flow through the system and for the next unit of capacity added to the system. It was determined that within a wide range of flows expected through the water or sewer system and for a given size of the system, unit operation and maintenance costs do not vary appreciably. Therefore, for all operation and maintenance cost categories, the current marginal cost was assumed to be equivalent to the current average cost.

For capital cost components, with the exception of water and wastewater treatment capital costs, the current marginal cost was also assumed to be equivalent to the current average cost. For water and wastewater treatment capital costs, the current marginal cost is the cost for the last increment of treatment capacity added to the system. Marginal treatment costs were determined from utility literature or utility personnel and are expressed on the basis of capacity. In some cases, the cost of the last increment of capacity was unavailable. If this was the case, the current average cost was used as the current marginal cost.

METHODOLOGY FOR PROJECTING COSTS

This section presents the methodology used to estimate future costs of providing potable water and wastewater disposal service in the MWA. Projections of costs were made through the year 2030 at five-year increments.

Uncertainties surrounding future inflation levels, utility plans, regulatory requirements, and future growth patterns in the MWA with the associated water demands and wastewater flows, significantly influence estimates of future costs. To overcome the influence of some of these uncertainties surrounding future conditions, the following simplifying assumptions were made:

1. Aside from known utility plans to change their systems, the existing types of systems will continue to be used.

2. Unless specifically known otherwise, utilities or agencies presently serving a jurisdiction will continue to serve that jurisdiction.

3. Present levels of treatment and current regulatory requirements will remain unchanged.

Given the above assumptions, the primary cause for rising unit costs is inflation. It was specified that a current net rate of inflation be applied to each of the functional cost categories. Net inflation represents the changes in costs in the particular category relative to changes of costs in the general economy. The Consumer Price Index (CPI) was used to gauge the rate of inflation in the general economy. To obtain an inflation rate for the functional cost categories, several specialized cost indices and numerous historical records of utility costs were reviewed. The average annual change of the CPI minus the average annual change in the applicable cost index or historical record over a specified time period was calculated to gauge the current net rate of inflation for that particular item. Table 4 shows the indices and historical records used to gauge the inflation rates for the functional categories indicated. Table 5 shows the average annual change of the CPI and selected other indices and records over a specified time period. It is evident from Table 5 that several different net inflation rates can be applied to each functional cost category depending upon the index used and on the time period over which the indices are compared. Therefore, the range of possible net inflation rates were reviewed and best judgment was exercised to select current net inflation rates.

For all the short-run variable cost components (water source pumping, water and wastewater treatment O&M, and water distribution, and wastewater collection pumping), an annual current net inflation rate of three percent was indicated. A three percent current net inflation rate was also applied to the administrative cost category. For all other operation and maintenance cost categories, the long-run variable and fixed components, which are variable with the capacity of the system, a two percent current net inflation rate was applied. Also, for all capital cost components a two percent current net inflation rate was used.

Once a net inflation rate was obtained, the changes in that rate over time were accounted for. It was specified the net inflation rate will decline to zero by 2005 at a constant percentage decrease per year and remain at zero through 2030. An index was generated for each net inflation rate with a 1980 base = 1.0 to allow for simple inflation of current costs into the future.

TABLE 4. ITEMS USED TO GAUGE INFLATION FOR THE FUNCTIONAL COST CATEGORIES

Item	Cost Category
Engineering New Record Construction Cost Index (ENR CCI)	All capital cost categories
U.S. EPA Index of Direct Costs for Operation, Maintenance and Repair of Municipal Wastewater Treatment Plants (OMR Index)	Treatment operation and maintenance costs
Chemical and Power Sub-Indices of EPA OMR WWTP Index	Short-run variable component of treatment O&M costs
USEPA OMR Cost Index for Municipal Raw Wastewater Pumping Stations	Pumping costs
Historical Records	All cost categories

TABLE 5. AVERAGE ANNUAL CHANGES IN SELECTED COST INDICES AND HISTORICAL COST RECORDS
(Changes were determined from 1967-1980 unless noted otherwise)

Item*	Average Annual Change (Percent)
CPI	7.2
ENR CCI	8.9
EPA STP OMR Index	8.7
Chemical Sub-Index	10.2
Power Sub-Index	11.2
EPA OMR Index for Municipal Raw Wastewater Pumping Stations	11.6
Historical Records**	
Administrative Costs	9.7
Water Treatment O&M	8.9
Water Aquisition O&M	10.1
Water Distribution O&M	10.1

* National average index values were used to calculate average annual changes.

** Historical records were obtained from Reference 2 and included the following: Rockville, WSSC, WAD and FCWA. Changes were averaged over the period 1967-1976. The average annual change of the CPI over that period was 6.1 percent.

Administrative Cost Projection

To project the future administrative cost associated with water supply and wastewater disposal in the MWA, the current marginal and average administrative cost was inflated at an initial three percent net inflation, and decreasing to zero by 2005. The index value at 5-year increments was multiplied by the current cost figure to obtain future cost figures. A sample calculation is shown in Appendix B under the Cost Projections heading.

Operation and Maintenance Costs Projections

As with the administrative cost category, forecasts of future costs were obtained by escalating current costs. The applicable net inflation rates as obtained earlier were used to inflate both current average and current marginal costs to obtain estimates of future costs.

Capital Cost Components Projections

With the exception of water and wastewater treatment capital costs, the capital cost components were treated similarly to the administrative cost component and operation and maintenance cost components. Both the current average and current marginal capital costs were inflated at the applicable declining net inflation rate to estimate future costs in the particular functional cost category.

To forecast future water and wastewater treatment capital costs, the timing, size, and cost of future treatment plant expansions were first determined. After the cost of each expansion was determined, annual unit costs were obtained, marginal and average costs were calculated, and the costs were allocated to the applicable jurisdictions. The detailed procedure for obtaining marginal and average treatment capital costs is outlined below. Sample calculations made in computing marginal and average treatment costs are shown in Appendix B.

Staging of Additional Capacity: Where available, actual utility plans were used to stage additional treatment capacity. Where unavailable, the following steps were taken:

Water Treatment Plants: The timing of future water treatment capacity additions was determined by comparing the existing treatment capacity of the utility in question with the projected water demand for that utility's service area. A treatment plant expansion was scheduled to go on-line at the time the existing capacity became inadequate. In all cases where a utility operates more than one plant, utility plans indicate that only one plant will be expanded to meet future water requirements. Future water demand used was that given in the MWA Water Supply Study for the Potomac Water Users: Draft Progress Report, Conservation and Demand Reduction Specialty Appendix under Conservation Senario Number 3. The size of the initial expansion (the procedure to size expansions is described later) was added to the existing capacity, and a second expansion was scheduled when the first additional increment was fully utilized. The procedure continued through 2030.

Wastewater Treatment Plants: Similar to staging of future water treatment capacity, the timing of additional wastewater treatment capacity was determined by comparing the existing capacity of the treatment plant with projections of future treatment capacity needed for the service area of the treatment plant. A capacity expansion was scheduled to go on-line when the existing capacity became inadequate. Projections of treatment capacity needed through the year 2000 for treatment plant service areas were obtained from the Metropolitan Washington Water Quality Management Plan: Plan Supplement, September 1980. Projections were trended to the year 2030 to obtain estimates of future capacity needed beyond the year 2000.

Staging of Additional Capacity: The size of both water and wastewater treatment capacity additions were obtained from utility plans where available. If utility plans were lacking, engineering judgment, considering such factors as the type and size of existing units, the sizes of past expansions, and ultimate site capacity was used to determine the size of future capacity additions.

Cost Estimates: After determining the timing and size of the next increment of treatment capacity, an estimate of its cost was made. As with staging and sizing of capacity additions, utility estimates of future costs were first utilized. If unavailable, the two cost estimating documents listed below were utilized.

1. Major Sewage Treatment Plants in the Washington Metropolitan Area, MWCOG, Washington, D.C., 1978.

2. Estimating Water Treatment Costs, MERL, U.S. EPA, Cincinnati, Ohio, July 1980.

The following assumptions were made in estimating water and wastewater treatment construction costs:

1. Estimates are for the full cost of expansion; i.e., no federal or state grants are received.

2. Unless utility plans indicated otherwise, new capacity is similar to existing treatment units.

3. Levels of treatment are assumed to remain constant.

Annualization: After the construction cost of the capacity addition was determined, the following steps were taken to obtain an annualized unit cost for treatment capacity:

1. If not already in 1980 dollars, the cost figure was adjusted to 1980 dollars using an appropriate index (Engineering News Record for Water Plants, and EPA Large City Advanced Wastewater Treatment Index for Wastewater Plants).

2. The 1980 cost figure was escalated at a two percent net inflation rate which decreases to zero by 2005, obtained as described earlier, to the mid-point of the construction period. The construction period was assumed to be four years ending at the time additional capacity is required.

3. The escalated cost was then adjusted for interest during the construction period by multiplying by an adjustment factor. The formula for the adjustment factor is shown in Appendix B.

4. Next, the escalated, adjusted cost was annualized at 3 percent interest over 30 years to obtain a stream of annual costs for each plant expansion. The annual cost was then divided by the capacity of the expansion to express the costs as unit capital costs.

Marginal Treatment Capital Cost: Marginal treatment capital costs are the costs for the next increment of treatment capacity. The current marginal cost, obtained as described earlier, was used as the marginal cost to the midpoint of the construction period of the first expansion at which time the costs for the first expansion became the new marginal cost. The cost of the first expansion was continued to the mid-point of the second construction period at which time the cost of the second expansion becomes the new marginal cost. The procedure continues through 2030.

Average Treatment Capital Cost: The average water and wastewater treatment capital cost was obtained by weighting the existing stream of capital costs, which are assumed to be equivalent to the current average cost obtained earlier, and the streams of capital payments due to each of the plant expansions according to the percentage of total plant capacity they contribute to. The weighted costs are then totaled to obtain an average capital cost for the plant.

Composite Marginal and Average Capital Costs: As illustrated on Figure 1, many of the jurisdictions in the MWA are served by more than one water treatment plant, and the majority are served by more than one wastewater treatment plant. As mentioned earlier, those utilities with more than one water treatment plant will expand a particular plant to meet future requirements so that the future marginal cost for the plant is equivalent to the future marginal cost for the utility as a whole. Also, since only a single plant is expanding, future costs are easily added to existing costs to obtain an average capital cost for the utility and for jurisdictions served by the utility.

For wastewater treatment plants, however, several plants are expanding and at different times to contribute to the utilities marginal and average capital costs. Where this was the case, a composite marginal and average cost was obtained by weighting the marginal and average costs for each plant contributing to a jurisdictions treatment costs according to the percentage of that jurisdictions flow treated at the particular plant. The weighted costs were totaled to obtain a composite marginal and average cost for the jurisdiction.

It is important to note that in calculating marginal and average capital costs, both the existing stream of capital payments and the streams of capital costs due to plant expansions were assumed to continue through 2030. The costs were continued to account for the practice of operating plants well beyond their economic life (here assumed to be equal to the amortization period of 30 years). This is accomplished by continually refurbishing or upgrading existing plant facilities. Alternatives to continuing the streams of capital payments would be to stop them at the end of 30 years, assuming no additional capital expenditures are incurred or to completely rebuild all of the existing capacity, resulting in large capital expenditures.

CURRENT AND PROJECTED COSTS

Using the methodology described, current and projected cost estimates were obtained for the portions of the MWA listed in Table 1. For two of the smaller jurisdictions, Indian Head and Occoquan/Woodbridge-Dumfries/ Triangle Sanitary District, insufficent cost data was obtainable to permit detailed cost estimates to be made. For each area, current and projected unit marginal costs, unit average or revenue-pricing water system costs and unit revenue pricing wastewater system costs were developed. Presented in Tables 6-65 are worksheets in which the costs for each area were tabulated. Costs are expressed on a cents per thousand gallons of revenue producing water for water-related costs and on a cents per thousand gallons of wastewater flow for sewer-related costs. In calculating future treatment capital costs, the capacity of expansions was used to obtain a unit cost. This is equivalent to using the flow at the point in time when the capacity addition is fully utilized to calculate a unit cost. Therefore, the stream of unit costs for each plant expansion, as identified by a jump in the treatment capital cost, tends to be understated to the point where the capacity is fully utilized.

DISCUSSION OF UNCERTAINTIES SURROUNDING FUTURE COSTS

As mentioned under the section on cost projections, several simplifying assumptions concerning future conditions were made. These were necessary since the precise nature of future conditions influencing the costs of water supply and wastewater disposal are difficult, if not impossible, to predict. However, it is possible to identify some of the more prominent factors potentially influencing costs and examine the general nature and extent of their influences. Since individual utilities would be impacted differently, only a general discussion is possible.

Among the more prominent items influencing future costs are federal and state regulations concerning the quality of drinking water and the protection of ground and surface water supplies.

The impact of regulations is evidenced by recent increases in the cost of wastewater disposal due to more stringent effluent limitations for wastewater treatment plants which have necessitated the addition of advanced waste treatment facilities. For the purposes of this study, it was assumed that the types of facilities currently in use will continue to be used in the future and that levels of treatment will remain unchanged. Since virtually all utilities in the MWA have already or are currently in the process of upgrading their treatment processes to provide advanced treatment, these increased costs are reflected in the cost estimates developed. Both operation and maintenance and capital costs have risen as a result and are expected to continue to increase for those jurisdictions whose advanced waste treatment facilities are just beginning to come on line. The magnitude of those cost increases, which depends on the size and type treatment facilities added and the required effluent quality, will vary from utility to utility. Recent increases in operation and maintenance costs for local utilities are in general agreement with an analysis by EPA which indicated that total wastewater treatment operation and maintenance costs increased an average of 33 percent due to upgrading from secondary treatment to advanced waste treatment for all of the plants surveyed.

A regulation of particular concern to area water suppliers is an amendment proposed by EPA on February 9, 1978 to change the National Interim Primary Drinking Water by adding regulations for organic contaminants in drinking water. The proposed amendment consists of a maximum contaminant level of 0.10 mg/l for trihalomethanes and a treatment technique requiring granular activated carbon for the control of synthetic organic chemicals. Since the proposed amendments are initially applicable to community water systems serving a population of more than 75,000, the costs of water supply for most residents of the MWA would be affected. In developing the cost estimates, it was assumed that existing water treatment facilities will continue to be used in the future and that levels of treatment will remain unchanged, so the impact of these regulations are not reflected in the costs developed. The exact extent of the impact on future costs is difficult to predict and would vary from utility to utility depending upon the current treated water quality and water supply system. Although area utilities contacted expect costs to increase if the proposed amendment is enacted, they do not expect a dramatic increase in the overall cost of supplying water.

EPA has estimated an average family's water bill would increase by about 10-20 dollars per year from installing granular activated carbon treatment.(11) Based on an average water consumption of 65 gpcd and an average cost of water of $1.00 per thousand gallons, the average family's water bill would increase 11-21 cents/1000 gallon purchased or 11-21 percent of the annual water bill.

Another area of concern with respect to future costs of water supply and wastewater disposal is the environmentally sound disposal of solid residues from water and wastewater treatment processes. Regulations are forcing several local utilities to abandon their current sludge disposal practices and adopt more environmentally sound and more costly methods of sludge disposal. Also, as existing facilities for sludge disposal become fully utilized, the costs for additional sludge disposal are expected to be proportionally higher due to increased land costs, higher costs from hauling over larger distances, and greater capital investments. The problem of sludge disposal is becoming even more important with the increasing use of advanced wastewater treatment processes which tend to generate higher levels of residual solids.

For the purposes of the study, it was assumed that existing methods of sludge disposal will be used in the future, and changed costs from different sludge disposal methods are not reflected in the costs developed. As with the impact of the proposed drinking water regulations, future costs of sludge disposal would be variable from utility to utility and the magnitude of those changes would be difficult to predict.

A final area of uncertainty concerning future costs are changes in the types of systems currently in use. It was assumed in the study that existing types of systems would continue to be used into the future. Depending upon the nature of the change, different types of systems could either increase or decrease costs. Although it is conceivable that technological improvements in water supply and wastewater disposal processes could reduce operating costs, it is likely that such improvements would involve increased capital expenditures and would involve a considerable lag time before the improved processes would impact the overall level of costs. Changes in the types of systems are more likely to occur as discussed earlier, due to more stringent regulations and would tend to increase the costs of water supply and wastewater disposal.

ACKNOWLEDGEMENTS

Following is a list of utility, Environmental Protection Agency, and local government personnel contacted to provide cost information. Their assistance and guidance in obtaining the needed information is gratefully acknowledged.

ALEXANDRIA SANITATION AUTHORITY
- Mr. Sam Shafer
- Mr. Jim Canaday

ARLINGTON COUNTY DEPARTMENT OF PUBLIC WORKS
- Mr. Angel
- Mr. Dave Timbie

DISTRICT OF COLUMBIA DEPARTMENT OF ENVIRONMENTAL SERVICES
- Mr. Ed Ligenfelter
- Mr. Russ Thomas

ENVIRONMENTAL PROTECTION AGENCY
- Mr. Robert Clark, Municipal Environmetal Research Laboratory, Cincinnati, Ohio
- Mr. Robert Michael, Municipal Construction, Washington, D.C.
- Mr. John Smith, Municipal Environmental Research Laboratory, Cincinnati, Ohio

FAIRFAX CITY DEPARTMENT OF WATER AND SEWER SERVICES
- Mr. Rich Fruhauf

FAIRFAX COUNTY DEPARTMENT OF PUBLIC WORKS
- Mr. Gozikowski
- Mr. Frank Houser
- Mr. Jack Liedl

FAIRFAX COUNTY WATER AUTHORITY
- Mr. James A. Warfield, Jr.
- Mr. Fred Griffith

FALLS CHURCH PUBLIC UTILITIES DEPARTMENT
- Mr. Howard Smith

METROPOLITAN WASHINGTON COUNCIL OF GOVERNMENTS
- Mr. Dan Booker

ROCKVILLE DEPARTMENT OF PUBLIC WORKS
- Mr. John Lawton
- Mr. J. Morningstar
- Mr. Lunking

VIRGINIA-AMERICAN WATER COMPANY
- Mr. Ted Jones

WASHINGTON AQUEDUCT DIVISION OF THE U.S. ARMY CORPS OF ENGINEERS
- Mr. Harry Ways, Chief WAD

WASHINGTON SURBURBAN SANITARY COMMISSION
- Mr. William Marlow
- Mr. Douglas N. Isokait
- Mr. T. Shagogue
- Mr. Joseph T. Carrigan, Jr.

REFERENCES

Utility Literature:

ALEXANDRIA SANITATION AUTHORITY
City of Alexandria, Virginia. Sanitation Authority Final Budget for the Fiscal Year Ending September 30, 1981.

ARLINGTON COUNTY DEPARTMENT OF PUBLIC WORKS
Arlington County, Virginia, Fiscal Year 1980 and 1981 Adopted Budgets.
Arlington County, Virginia, Fiscal Year 1980-1985 Capital Improvements Program.
Arlington County, Virginia, Fiscal Year 1982-1987 Preliminary Capital Improvement Program.
Montgomery Engineers of Virginia, Inc. for Arlington County Department of Public Works, "Arlington County Water System Study," March 1980.
Timbie, David P. "Financial Impact of the Arlington County, Virginia AWT Project," October 1979.

DISTRICT OF COLUMBIA DEPARTMENT OF ENVIRONMENTAL SERVICES
Fiscal Year 1982 Executive Budget, District of Columbia Government, October 1980.
Justifications for the Fiscal Year 1982 Budget, District of Columbia Government, October 1980.

FAIRFAX CITY DEPARTMENT OF WATER AND SEWER SERVICES
City of Fairfax Proposed General Fund, Capital Improvements, and Utility Fund Budgets for Fiscal Year 1980-1981.

FAIRFAX COUNTY DEPARTMENT OF PUBLIC WORKS
Fairfax County Wastewater Treatment Division Fiscal Year 1982 Proposed Budget.

FAIRFAX COUNTY WATER AUTHORITY
FCWA Capital Improvements Program: 1980-1985, Adopted February 1980.
FCWA Final Draft Annual Report 1979.
FCWA Preliminary Water System Budget for the Fiscal Year Ended December 31, 1981, October 1980.
FCWA Revenue Bonds, Series 1979, July 1979.

FALLS CHURCH PUBLIC UTILITIES DEPARTMENT
Public Utilities Department - Miscellaneous Data 1979-1980.

ROCKVILLE DEPARTMENT OF PUBLIC WORKS
Annual Financial Report for the Fiscal Year Ended June 30, 1979, City of Rockville, Maryland.
Fiscal Year 1981-1986 Adopted Capital Improvements Program, City of Rockville, Maryland.
Sanitary Sewer Fund Projection FY 1977-1986, Financial Sheet.
Water Facility Fund Projection FY 1977-1986, Financial Sheet.

VIRGINIA-AMERICAN WATER COMPANY
Annual Report of Virginia-American Water Company - Alexandria District for the Year Ended December 31, 1979.
Annual Report of Virginia-American Water Company - Prince William Distric for the Year Ended December 31, 1979.
Financial and Operating Data: Investor Owned Water Utilities, National Association of Water Companies, 1978.

WASHINGTON AQUEDUCT DIVISION OF THE U.S. ARMY CORPS OF ENGINEERS
Fiscal Year 1982 Executive Budget, District of Columbia Government, October 1980.
Justifications for the Fiscal Year 1982 Budget, District of Columbia Government, October 1980.
Haskins and Sells for WAD U.S. Army Corps of Engineers, "Wholesale Water Rates and Rate Making Methods," March 1977.

WASHINGTON SURBURBAN SANITARY COMMISSION
WSSC Comparative Financial Statements for the Fiscal Year Ending June 30, 1980.
WSSC Cost Studies, June 1979.

General References:

1. Alpert, Mark E. and Ward, Daniel S. "Major Sewage Treatment Plants in the Washington Metropolitan Area." Metropolitan Washington Council of Governments, Washington, D.C., 1978.

2. Clark, Robert M., et al. "Analysis of the Economics of Water Supply in the Washington Metropolitan Area." Municipal Environmental Research Laboratory, U.S. EPA, Cincinnati, Ohio, July 1980.

3. Gummerman, Robert C., Culp, Russel L., and Hansen Siguard P. "Estimating Water Treatment Costs: Volumes 1-3." Municipal Environmental Research Laboratory, U.S. EPA, Cincinnati, Ohio, February 1980.

4. Metropolitan Washington Council of Governments. "Metropolitan Water Quality Management Plan." MWCOG: Water Resources Planning Board, Washington, D.C., March 1978.

5. Metropolitan Washington Council of Governments. "Metropolitan Washington Water Quality Management Plan: Plan Supplement." MWCCG: Water Resources Planning Board, Washington, D.C., September 1980.

6. Stevie, Richard G., Clark, Robert M., and Adams, Jeffrey Q. "Managing Small Water Systems: A Cost Study." Municipal Environmental Research Laboratory, U.S. EPA, Cincinnati, Ohio, September 1979.

7. Robert, L. Michael. "Comparisons of Cost, Manpower Utilization, and Flow in Operation and Maintenance of Investor-Owned Water Companies and Municipal Wastewater Systems." U.S. EPA Unpublished Report, June 1979.

8. U.S. Army Corps of Engineers, Baltimore District. "Metropolitan Washington Area Water Supply Study for the Potomac Water Users: Draft Progress Report-Main Report, Supply and Demand Specialty Appendix, Conservation and Demand Reduction Specialty Appendix." August 1979.

9. U.S. Army Corps of Engineers, Baltimore District. "Metroplitan Washington Area Stage II Draft Report: Outlying Service Areas and Long-Range Alternatives." April 1980.

10. U.S. EPA. "Analysis of Operation and Maintenance Costs for Municipal Wastewater Treatment Plants: Technical Report." Office of Water Program Operations. Washington, D.C., February 1978.

11. U.S. EPA. "EPA Journal." September 1978.

12. U.S. EPA. "Innovative and Alternative Technology Assessment Manual." Municipal Environmental Research Laboratory, Cincinnati, Ohio, February 1980.

APPENDIX A: MAJOR WATER SUPPLY AND WASTEWATER DISPOSAL SYSTEMS IN THE MWA*

INTRODUCTION

The MWA is served by a number of water supply and wastewater disposal utility agencies. Table 2 presented in the Introduction, shows the principal operating agencies responsible for providing potable water and for disposal of wastewater in the major political jurisdictions in the region, indicating the service(s) they provide. Presented here are an overview of water supply and wastewater disposal in the MWA and a summary description of water supply and wastewater disposal systems operated and maintained by the principal utility agencies within the region.

Of a total of 25 independent water supply systems in the MWA, three: The Washington Surburban Sanitary Commission (WSSC), the Washington Aqueduct Division (WAD) of the U.S. Army Corps of Engineers; and the Fairfax County Water Authority (FCWA) provide about 95 percent of the total water treatment capacity in the MWA. Figure A-1 shows these agencies' service areas and the location of both their existing and proposed treatment facilities. Table A-1 presents a summary of major water treatment facilities in the region, proposed expansion programs, sources of water supply, types of treatment, and plant capacities.

As can be seen in Table A-1, surface water is the primary raw water source for the MWA, supplying greater than 99 percent of the total water supplied. The Potomac River, which accounted for approximately 70 percent of surface water supplied in 1976, is the principal water source. Lesser amounts were extracted from the Patuxent River (12 percent), Broad Run (1 percent), and Beaverdam Run (1 percent). Groundwater, used principally in outlying areas, supplies less than one percent of the total water supplied. As evidenced by current expansion programs, future water demands will be met primarily from the Potomac.

More than a dozen wastewater treatment facilities ranging in size from 0.1 MGD to over 300 MGD serve the MWA. Table A-2 lists the major wastewater treatment facilities serving the MWA, their current capacities and the responsible operating agency. As shown in Figure A-2, the majority of these plants are located along the Potomac River with the remaining plants located along the Patuxent River or Occoquan Creek.

All of the wastewater treatment plants in the MWA utilize biological treatment processes to provide treatment through the secondary level, with the majority employing some type of activated sludge process. A major plant not employing an activated sludge process is the Alexandria plant which utilizes rotating biological contactors. All plants have or will soon have advanced wastewater treatment facilities providing further BOD and suspended solids removal, phosphorous removal, and some form of nitrogen conversion or removal. Table A-3 presents the treatment trains utilized by the principal treatment plants in the region, and Table A-4 presents the on-site solids handling systems utilized by those plants.

* System descriptions were obtained from the utility specific literature and References #1 and #2 shown in the Reference section of the main report.

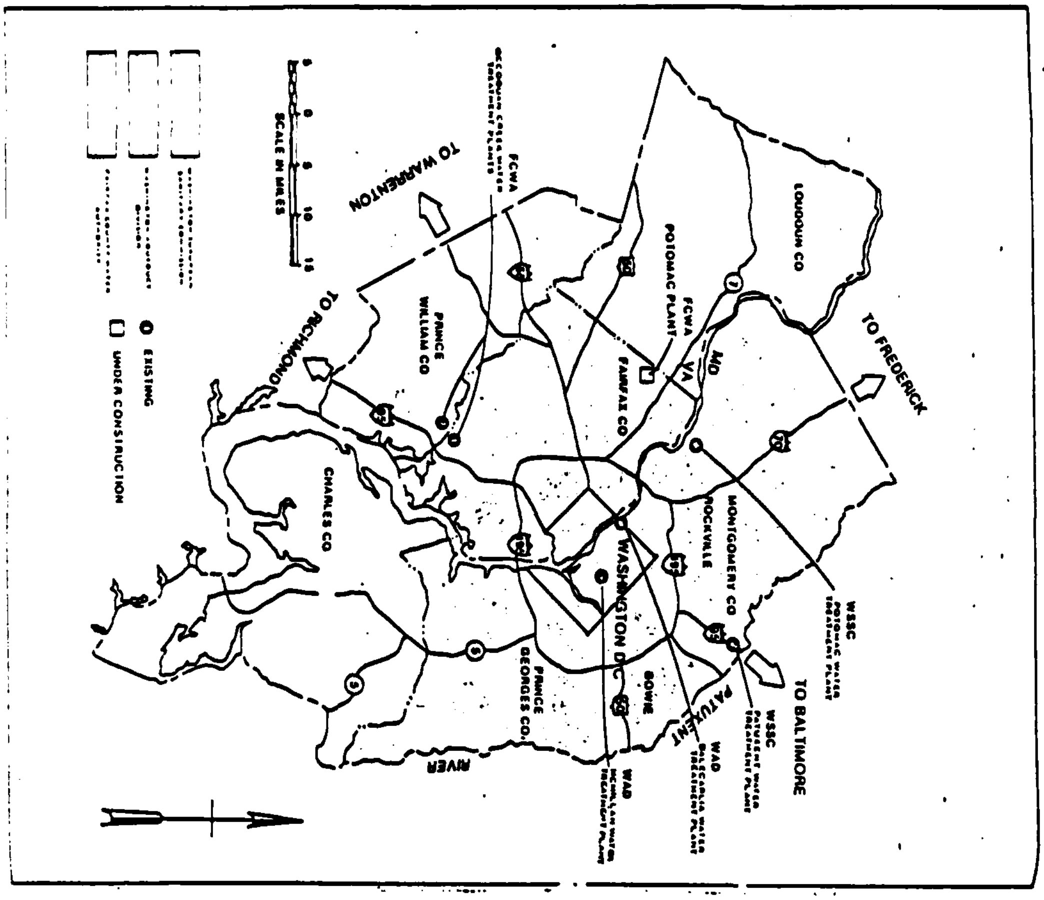


Figure A-1. Major Water Supply Systems in the MWA

Source: From Metropolitan Washington Area Water Supply Study for the Potomac Water Users: Draft/Progress Report Supply and Demand Specialty Appendix, U.S. Army Corps of Engineers, Baltimore District, August 1979, p. 84.

WATER SOURCE	WATER SYSTEM	INTAKE CAPACITY (mgd)	RAW WATER TREATMENT PLAN: TREATMENT PLANTS	TYPE OF TREATMENT	CAPACITY (mgd)	MAXIMUM CAPACITY (mgd)	PROPOSED EXPANSION PROGRAM
Potomac River	Washington Aqueduct	650	Dalecarlia	Conventional* Treatment (Rapid Sand Filter)	164	246	
			McMillan	Conventional Treatment (Slow Sand Filter),	100	125	
	Washington Suburban Sanitary Commission	184	Potomac	Conventional Treatment.	160	240	Construction of 400 mgd Potomac Intake Structure and expansion of Potomac River Filtration Plant to maximum capacity of 400 mgd. Scheduled completion dates: Structures - 1984 30 mgd pumps as needed.
	Fairfax County Water Authority				47	70	Construction of 200 mgd Potomac Intake Structure, construction of 200 mgd Potomac River Filtration Plant. Construction of Plant initiated November 1978. Scheduled completion dates: Structures 1981 - 30 mgd pumps as needed.
	Rockville	8	Rockville	Conventional Treatment	8	8	
Occoquan Creek	Fairfax County Water Authority	100	Occoquan	Conventional Treatment	84	112	
Patuxent River	Washington Suburban Sanitary Commission	94	Patuxent	Conventional Treatment	49	65	
Broad Run	Manassas, Va.			Conventional Treatment	5	6	Study for expansion in progress.
Goose Creek	Fairfax (City)			Conventionl Treatment	8	10	Two-stage expansion of water treatment plant - 1st stage from existing 9 mgd to 18 mgd, 2nd stage from 18 mgd to 27 mgd. Scheduled completion dates: 1st stage - 1980 2nd stage - 1983
TOTAL					624	791	

*Conventional Treatment (coagulation, sedimentation, filtration, and disinfection)

Table A-1. Existing Water Treatment Facilities and Proposed Expansion Programs in the MWA

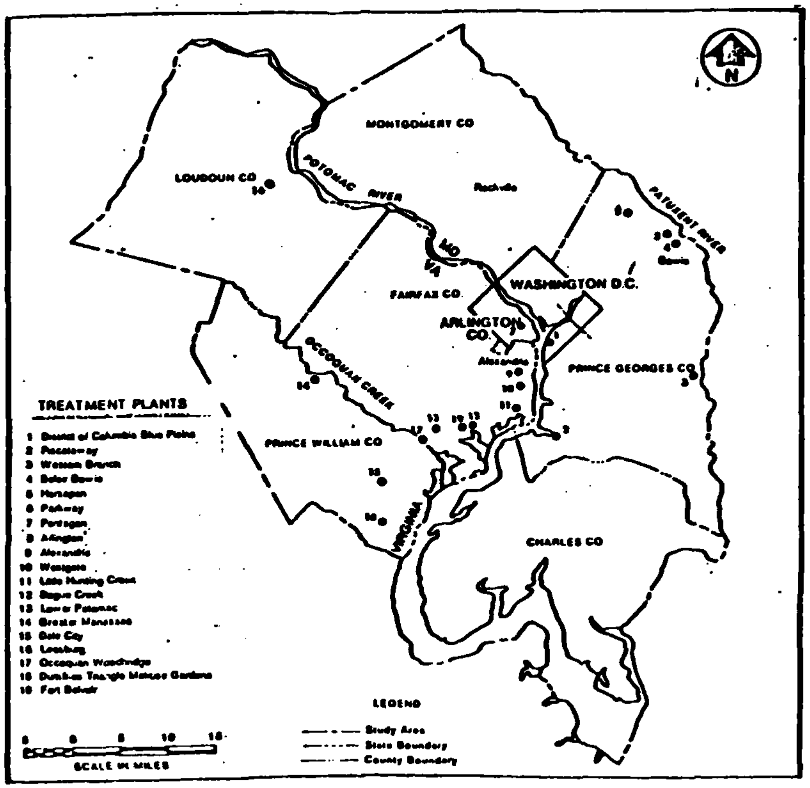
Source: From Metropolitan Washington Area Water Supply Study for the Potomac Water Users: Draft Progress Report Supply and Demand Specialty Appendix, U.S. Army Corps of Engineers, Baltimore District, August 1979, p. 85.

TABLE A-2. MAJOR WASTEWATER TREATMENT FACILITIES IN THE MWA

Facility	Capacity (MGD)	Operating Agency
District of Columbia Blue Plains	309	D.C. Dept. of Environmental Services
Piscataway	30	Washington Surburban Sanitary Commission (WSSC)
Western Branch	30	WSSC
Parkway	7.5	WSSC
Horsepen	1.0	WSSC
Bowie/Belair	2.6	City of Bowie
Arlington	30	Arlington County DPW
Lower Potomac	36	Fairfax County DPW
Little Hunting Creek	6.6	Fairfax County DPW
Alexandria	54	Alexandria Sanitation Authority
UOSA	15	Upper Occoquan Sanitation Athority
Dale City	4.0	Dale Service Corporation
Mooney Potomac	12.0	Occoquan/Woodbridge-Dumfries/ Triangle Sanitary District
Matawoman	5.0	Charles County Sanitary Commission
Leesburg	1.2	Town of Leesburg

Figure A-2. Location of Major Wastewater Treatment Plants in the MWA

Source: From Metropolitan Washington Area Water Supply Study, Stag II Draft Report: Outlying Service Areas and Long-range Alternatives, U.S. Army, U.S. Army Corps of Engineers, Baltimore District, April 1980, p. B-IV-35.



NOTES:

1. Pentagon WWTP is no longer operational. Pentagon flows are treated at Arlington WWTP.
2. Douge Creek and Ft. Belvoir WWTP's have been abandoned. Their flows are now treated at the Lower Potomac WWTP.
3. Occoquan Woodbridge and Dumfries Triangle Melrose Gardens WWTP's are not longer operational. Their flows are now treated at the UOSA WWTP located in Prince William County.
4. Greater Manassa plant is no longer operational. Its flows are now treated at the Moorey Potomac WWTP located in Prince William County.

TABLE A-3. WASTEWATER TREATMENT TRAINS FOR THE PRINCIPAL WASTEWATER TREATMENT PLANTS IN THE MWA

PLANT	Preliminary Treatment	Primary Treatment	Secondary Treatment	Phosphorus Removal: Alum	Phosphorus Removal: Ferric Chloride	Phosphorus Removal: Lime	Nitrogen Conversion Removal: Nitrification	Nitrogen Conversion Removal: Denitrification	Nitrogen Conversion Removal: Ion Exchange	Nitrogen Conversion Removal: Breakpoint Chlorination	Carbon Adsorption	Filtration	Disinfection	Reaeration	Effluent Reservoir
Patuxent															
Parkway STP	•	•	•				•					•	•	•	
Western Branch STP	•		•				•					•	•	•	
Potomac Mainstem															
Piscataway STP	•	•	•	•			•					•	•	•	
Blue Plains STP	•	•	•		•		•	•				•	•		
Virginia Embayments															
Mooney Potomac STP	•	•	•	•			•				•	•	•	•	
Alexandria STP	•	•	•	•					•	•	•	•	•		
Arlington STP	•	•	•			•				•	•	•	•	•	
Lower Potomac STP	•	•	•			•				•	•	•	•	•	
Above Water Intakes															
Dickerson STP	•	•	•			•				•	•	•	•		•
UOSA STP	•	•	•			•			•	•	•	•	•		•

Preliminary Treatment - Removal of large objects and heavy inorganic solids.

Primary Treatment - Removal of settleable organic solids.

Secondary Treatment - Conversion of soluble organic matter to carbon dioxide, water, and biomass, and removal of excess biomass.

Phosphorus Removal:

- Alum - Precipitation of phosphorus as aluminum phosphate, aggregation of the chemical precipitate, and removal of the aggregated particles.
- Ferric Chloride - Precipitation of phosphorus as ferric phosphate, aggregation of the chemical precipitate, and removal of the aggregated particles.
- Lime - Precipitation of phosphorus as calcium phosphate, aggregation of the chemical precipitate, and removal of the aggregated particles.

Nitrogen Removal:

- Nitrification - Conversion of ammonia nitrogen to nitrite and nitrate nitrogen with by-products of hydrogen, water, and biomass and removal of excess biomass.
- Denitrification - Conversion of nitrite and nitrate nitrogen to nitrogen gas with the production of excess biomass.
- Ion Exchange - Removal of ammonia nitrogen by exchange of ammonium ions for calcium, magnesium, or sodium ions on a zeolite resin.
- Breakpoint chlorination - Oxidation of ammonia nitrogen to nitrogen gas by the addition of chlorine.

Carbon adsorption - adsorption of residual, soluble organics.

Filtration - Removal of non-settleable solids.

Disinfection - Reduction in number of pathogenic organisms.

Reaeration - Elevation of dissolved oxygen content of effluent.

Effluent Reservoir - Retention of effluent for natural purification and recycle if the quality is unsatisfactory.

NOTE: The Dickerson WWTP Projec has been abandoned, and t Dickerson Plant will not be constructed.

SOURCE: From Draft Metropolitan Washington Water Quality Management Plan, Water Resources Planning Board, MWC06, March 1978.

TABLE A-4. ON-SITE SOLIDS HANDLING SYSTEMS FOR THE PRINCIPAL WASTEWATER TREATMENT PLANTS IN THE MWA

SOURCE: From Draft Metropolitan Washington Water Quality Management Plan, Water Resources Board, MWC06, March 1978.

PLANT	TYPE OF SOLIDS	Thickening	Digestion	Conditioning	Dewatering	Conversion: Incineration	Conversion: Composting	Furnace
Parkway STP	Organic	•		•	•	•		
Western Branch STP	Organic	•		•	•	•		
Piscataway STP	Organic/Chemical	•		•	•	•		
Blue Plains STP	Organic/Chemical	•		•	•	•	•	
Mooney Potomac	Organic/Chemical	•		•	•	•		
	Spent Carbon							•
Alexandria STP	Organic/Chemical	•	•	•	•			
	Spent Carbon							•
Arlington STP	Organic	•		•	•	•		
	Chemical (Lime)	•			•			•
	Spent Carbon							•
Lower Potomac STP	Organic	•		•	•	•		
	Chemical (Lime)	•			•			•
	Spent Carbon							•
Dickerson STP	Organic	•	•	•	•			
	Chemical (Lime)	•			•			•
	Spent Carbon							•
UOSA STP	Organic	•	•	•	•		•	
	Chemical (Lime)	•			•			
	Spent Carbon							•

Thickening - Separation of liquid from the sludge.
Digestion - Stabilization of solids and reduction in number of pathogenic organisms.
Conditioning - Modification of the properties of the sludge to render it more amenable to dewatering.
Dewatering - Separation of liquid from the sludge.
Incineration - Combustion of organic solids.
Composting - Stabilization of solidsand reduction in the number of pathogenic organisms
Furnaces - With lime sludge, conversion of calcium carbonate to calcium oxide which is reused to remove phosphorus. With spent carbon, volatization and oxidation of organic material adsorbed on the carbon which is reused to remove

NOTE: Dickerson WWT Project has been abandoned, and the Dickerson Plant will not be constructed.

WASHINGTON SURBURBAN SANITARY COMMISSION

The Washington Surburban Sanitary Commission (WSSC) provides water and sewerage services to residents of Montgomery and Prince Georges counties in Maryland. WSSC maintains extensive facilities relating to all aspects of providing potable water and for disposal of wastewater.

The WSSC obtains raw water from both the Patuxent and Potomac Rivers. Two raw water supply dams, the Tridelphia Lake and the T. Howard Duckett Dam, located at Brighton in Montgomery County and at Rocky Gorge in Prince Georges County respectively, are maintained on the Patuxent River. The Potomac is the principal water source, supplying approximately 70 percent of WSSC's needs. Located near each of the two rivers is a water treatment plant.

The Potomac Water Treatment Plant, Washington Surburban Sanitary Commission's principal water supply facility, is located at River Road two miles upstream from Great Falls in western Montgomery County. Water is drawn from the Potomac River at a point located upstream from Great Falls near Potomac, Maryland to supply to the Potomac plant. Although the plant has a maximum capacity of 240 MGD, capacity is currently limited to 180 MGD by the existing raw water intake and pumping station during normal river flows. Construction is underway to expand the intake to 400 MGD.

Water receives conventional treatment at the Potomac plant consisting of prechlorination, coagulation, settling, filtration, and fluroidation. Pumps rated at 1500 horsepower deliver water to the plant located 140 feet above the river. A venutri meter measures the rate of flow into the plant and is used to control the rate of chemical addition to the raw water. In the first step of the treatment process, chlorine is automatically fed to the raw water for disinfection and for taste and odor control. More chlorine and alum are added in a rapid mixing chamber as the water enters the headhouse. Following the rapid mixing chamber, are floculation basins which have a detention time of 30 minutes. After leaving the floculation basins, water enters settling basins which have a detention time of 2½ hours and then through rapid sand filters to water reservoirs with a storage capacity of 22 million gallons. Treated water is pumped through the finished water pumping station through pipelines up to 96 inches in diameter to distribution system.

The Patuxent Filtration Plant is located on Maryland Route 198, approximately 2 miles southwest of Duckett Dam in Prince Georges County. A 60 inch pipe routes water from the dam to the Rocky Gorge Raw Water Pumping Station 600 feet downstream, and from there, water travels through three parallal lines (sizes 30, 36, and 42 inches in diameter) to the filtration plant. It is a rapid sand filtration plant with a maximum one day capacity of 65 MGD. The plant consists of a three-story headhouse, four filter units, and filtered water storage areas and is of primarily steel construction. The headhouse contains the office, laboratory, chemical feeding equipment, central control panel, storage rooms and repair shop.

The independent filter units are of Morris-type design with each containing mixing chambers, settling basins, six rapid sand filters and the instruments, controls and piping necessary for their operation.

The water receives conventional treatment at the Patuxent plant consisting of prechlorination, coagulation, settling, filtration, corrosion control, and postchlorination or dechlorination.

Both the Patuxent and Potomac plants deliver treated water into an interconnected distribution consisting of over 3400 miles of pipeline. Approximately 49 water storage structures, low level reservoirs, stand pipes, and elevated tanks provide a storage capacity of approximately 160 million gallons. Also included in the distribution system are approximately 14 finished water pumping stations. Water is delivered to Montgomery and Prince Georges Counties and portions of Howard County.

In addition to their water system facilities, WSSC operates and maintains an extensive wastewater collection and disposal system. As of 1978, the wastewater collection system maintained by WSSC included approximately 3500 miles of sewer mains and about 227,000 sewer house conections. The collection system also included 52 wastewater pumping stations.

From the collection system, wastewater is delivered to either the Blue Plains Regional Wastewater Treatment Plant operated by the District of Columbia or to one of several wastewater treatment plants operated by WSSC. The principal plants operated by WSSC include the Piscataway, Western Branch, Parkway and Horsepen plants. At present, approximately 75 percent of WSSC's wastewater is treated at Blue Plains.

WASHINGTON AQUEDUCT DIVISION

The Washington Aqueduct Division of the U.S. Army Corps of Engineers supplys water to the District of Columbia, Arlington County and the City of Falls Church. Distribution of water within these areas is the responsibility of the local jurisdictions. In 1980, the WAD supplied approximately 74 billion gallons of treated water. Raw water is obtained from the Potomac River at intakes located near Great Falls and Little Falls, Maryland before being treated at the McMillan and Dalecarlia Water Treatment Plants.

The Dalecarlia Water Treatment, completed in 1928, is the Washington Aqueduct Division's primary treatment facility. The plant has grown from capacity of 80 MGD in 1928 to a present maximum capacity of 246 MGD. From the Little Falls and Great Falls raw water intakes on the Potomac River, water is delivered to the Dalecarlia Reservoir where it receives one and a half days of pre-sedimentation prior to treatment at the Dalecarlia plant.

Treatment at Dalecarlia consists of conventional treatment (coagulation, sedimentation, filtration, disinfection, pH adjustment) and fluoridation. Carbon for taste and odor control, chlorine for disinfection and oxidation of organic matter, and aluminum sulfate in the form of a liquid solution of crystal alum to aid in the removal of suspended matter are all added to raw water entering the plant. Mixing of the chemicals and floculation occur in mechanical floculation chambers located at the influent end of the sedimentation basins where the alum floc settles. The original plant contained two concrete sedimentation basins each 335 feet long, 150 feet wide, and 12 to 17 feet deep. Two, two-story floculation-sedimentation basins were later added, one in 1949 and the other in 1966. The floculation section, located in the lower story and containing six rows of paddles 14 feet in diameter, has a capacity of 1.64 MG, a detention time of 45 minutes and an average velocity of 2.6 feet per minute. The lower sedimentation basin is 316 feet long, 138 feet wide and 15 feet deep while the upper basin is 460 feet long, 138 feet wide, and 15 feet deep with a total capacity of 12.1 MG. During operation of the two-story floculation sedimentation basins, water enters the floculation basin through distributing ports, flows through the lower sedimentation chamber, and then flows upward and backward through the upper chamber and then out the effluent chamber. Total detention time ranges from 4 - 30 hours. Prior to filtration, carbon and chlorine may be added for taste and odor control and sulfur oxide may be added to remove excess chlorine. From the sedimentation basins water is applied to dual-media (sand and crushed anthracite coal) rapid sand filters at a design rate of 2 gallons per minute per square foot of filter surface area. The older filter units have a capacity of 4 MGD each, and the newer units have a rated capacity of 6 MGD. Filters are periodically backwashed using filtered water stored in two wash water reservoirs.

After filtration, chlorine is added to the water for taste and odor control and to maintain a chlorine residual. Sulfure oxide may also be added to remove excess chlorine. Hydrated lime is added for pH adjustment and for corrosion control in the distribution system and finally, fluoride

is added for fluoridation. Treated water is stored in clear water basins with a total capacity of 40 MGD before being pumped to four service areas within the District of Columbia and to Arlington County and Falls Church in Virginia.

The McMillan Water Treatment Plant is a slow sand filtration plant originally built in 1905 and is operated by the Washington Aqueduct Division of the U.S. Army Corps of Engineers. It has a maximum capacity of 125 MGD. The Potomac River is the source of water for the McMillan plant. However, prior to reaching the McMillan sand filters, raw water receives pretreatment at the Dalecarlia and Georgetown Reservoirs. Raw water pumped from the Potomac first receives 1½ days of pre-sedimentation at the Dalecarlia, and upon leaving Dalecarlia, carbon, fluoride, aluminum sulfate, and chlorine are added to the water. Mixing of chemicals and floculation occur in the conduit by the turbulent energy generated during flow to the Georgetown Reservoir where the floc settles in two sections of the reservoir which have paved floors. Sedimentation continues in a third section of the reservoir for a total detention time of 1½ to 3 days. Effluent from the Georgetown Reservoir travels 4 miles through the Washington City Tunnel to the McMillan Storage Reservoir where it receives an additional 1-1½ days of sedimentation before being pumped to the McMillan Filtration Plant.

The McMillan plant consists of 29 slow sand filter beds each with an area of one acre, the necessary sand bins and regulator houses, and administration and maintenance buildings. The filters are constructed of groined arch reinforced concrete and contain 20 inches of sand supported by 12 inches of graded crushed stone. Water, with a turbidity as low as 2 or 3 parts per million, is applied to the filter beds, and the effluent is collected in an underdrain system consisting of 6 and 12 inch pipes laid with open joints feeding a 24 inch control tile collector. Chlorine for disinfection and hydrated lime for pH adjustment are added to the water before it is delivered to two connected clear well basins with a combined capacity of 33 million gallons. Finished water from McMillan is pumped to service areas with the District of Columbia.

FAIRFAX COUNTY WATER AUTHORITY

Fairfax County Water Authority is the largest water supplier in Virginia, serving an estimated 653,800 people in 1979. Its service area includes most of Fairfax County, the City of Alexandria through the Virginia-American Water Company and to portions of Prince William County. The system has undergone rapid growth in the past and continued growth is expected in the future.

The current principal source of water for the Authority, supplying 90 percent of its needs, is the Occoquan River which is impounded by two concrete dams near the town of Occoquan, Virginia. The impounded Occoquan River supply has a safe yield of appoximately 65 MGD. A two foot high addition to the top of the larger dam will increase the capacity of the upper dam by 1.1 BG, increasing the reliability of the raw water supply. Additional sources of water include 23 wells and the purchase of water from the cities of Fairfax and Falls Church and from Ft. Belvoir. To meet projected future water demands, the Authority is developing additional supply facilities on the Potomac River. Additional capacity of 200 MGD will be provided by the facilities which are expected to become the major source of supply while the Occoquan supply is used to supply peak demands.

Unfinished water is currently treated at two interconnected plants built in stages from 1950 to 1972 along the bank of the Occoquan River near the town of Occoquan. Collectively, the Occoquan facilities have an average daily capacity of 84 MGD and a maximum capacity of 111.6 MGD. Raw water is delivered to the plants through a 100 MGD intake structure located near the base of the lower dam. Raw water receives conventional treatment consisting of coagulation, sedimentation, filtration, disinfection and fluoridation. Chemicals used include chlorine for disinfection, manganese and iron removal, and taste and odor control; activated carbon for taste and odor control; alum for coagulation; lime to increase alkalinity, assist coagulation, and to inhibit corrosion; potassium permagnate for magnesium removal; sodium bisulfite for dechlorination; and fluoride to retard tooth decay. Six finished water tanks with a storage capacity of over 6 million gallons are also located at the plant.

Treatment facilities for the Potomac River supply are to be constructed in 50 MGD increments to a total of 200 MGD, with the first increment expected to be operational by the spring of 1982. The treatment plant is located on a 112-acre site on Route 680, just south of Route 7 in Fairfax County. A raw water pump station equipped with three electric pumps providing a capacity of 50 MGD will supply water to the plant.

Additional pumps will be installed as needed to an ultimate capacity of 200 MGD. The following treatment processes will be used at the Potomac facility: application and mixing of chemicals, sedimentation, filtration, fluoridation, and disinfection. Suspended solids, removed during sedimentation and filtration, will be dewatered using filter presses, and the residue

will be disposed of at an approved landfill site. Underground finished water storage reservoirs and a finished water pumping station will also be located at the plant site.

Presently, some twenty pumps deliver water to the distribution system with an additional 24 booster pumping stations located throughout the distribution system which contains about 1,635 miles of water mains and about 9000 fire hydrants. Nearly 21 million gallons of water are stored in 40 water tanks throughout the service area. The system is interconnected at 69 locations with 12 other water systems in Northern Virginia. Approximately 10.3 miles of 36-48 inch transmission mains, serving the western part of Fairfax County and interconnected with existing mains will be installed in conjunction with the new Potomac facilities. An additional 2.7 miles of 30-inch pipeline will be installed to serve the northwest portions of the county.

VIRGINIA-AMERICAN WATER COMPANY

The Virginia American Water Company is a private firm which supplies water to the city of Alexandria and to the Dale City area of Prince William County.

Treated water purchased from the Fairfax County Water Authority is the primary source of water. Approximately 13 MGD were purchased in 1980. Purchased water is supplemented by three wells with depths of 380, 358, and 199 feet respectively which can provide a total yield of about 2 MGD. Fluoride, calgon, caustic soda, and chlorine are added at the well sites for purification of the well water.

As of 1979, the distriubtion system serving the Alexandria District included approximately 218 miles of distribution mains, three storage reservoirs with a combined storage capacity of 16.7 MG, and two storage tanks with a combined capacity of 1.75 MG. Also included in the distribution system are two electric and three diesel pumping facilities which have a combined pumping capacity of 12.92 MGD. Distribution facilities serving the Prince William District include approximately 91 miles of distribution mains, two storage tanks with a total storage capacity of 3.25 MG, and six electric pumping facilities with a combined pumping capacity of 21.15 MG.

ROCKVILLE DEPARTMENT OF PUBLIC WORKS

The City of Rockville, Department of Public Works supplies water to City residents and to a few customers in surrounding Maryland. Raw water is obtained from the Potomac River through an intake on the towpath of the Chesapeake and Ohio Canal near Swains Lock. Three submersible pumps each rated at a delivery of 3,100 gallons per minute at a total dynamic head of 114 feet deliver water to the treatment plant located just over one-fourth mile from the intake. The Rockville system is also interconnected with the WSSC water system for an estimated potential supply of four million gallons per day.

The treatment plant began operation in 1958. Additional units were added in 1967 for a present total maximum daily capacity of 8 MGD. The plant consists of two up-flow contact pre-sedimentation basins, four two-bay filters, and a three-story plant building. Each clarification basin has a maximum design flow rate of 6 MGD and each contains zones for mixing chemicals, floculation and settling. The filter units, containing 2 feet of graded anthracite coal on top of four layers of graded gravel, have a filter rating of 2 gallons per minute per square feet of surface area for a total capacity of 2 MGD each.

Three high service pumps each rated at 2,800 gallons per minute deliver water to the distribution system which contains approximately 140 miles of water mains and over 1000 fire hydrants. Five finished water storage facilities are also located within the city.

As of 1979, over 140 miles of sanitary sewer were maintained by the Department of Public Works. Further conveyance of wastewater and treatment is provided by WSSC. Wastewater is treated at the Blue Plains Regional Treatment Plant.

FAIRFAX CITY DEPARTMENT OF WATER AND SEWER SERVICES

Fairfax City Department of Water and Sewer Services supplies water from its own facilities to residents of the city. The city also provides water on a wholesale basis to the Loundon County Sanitation Authority, Fairfax County Water Authority, and the Town of Herndon. The city owns and maintains two water reservoirs located in Loundon County approximately seven miles northwest of Sterling Park, Virginia. The smaller of the two reservoirs holding approximately 200 million gallons is located on Goose Creek, and the larger reservoir holding 1.3 billion gallons is located about two miles upstream on Beaverdam Creek, a tributary to Goose Creek. The Beaverdam Lake provides four months of water supply against drought and low flow conditions in Goose Creek.

Raw water is withdrawn from the Goose Creek Reservoir through a 24 inch diameter intake and is pumped to the Goose Creek Water Treatment Plant located approximately one-half mile to the east of the dam. The pumping station houses four pumps, three with a nominal capacity of 4.0 MGD each and one with a nominal capacity of 1.5 MGD. The raw water receives conventional treatment consisting of coagulation, sedimentation, filtration and disinfection. The original plant, built in 1960, at a cost of 5 million dollars, has an average design capacity of 6 MGD and a maximum design capacity of 9 MGD. The City is in the process of expanding the Goose Creek plant to a base capacity of 11 MGD and a maximum capacity of 15 MGD. A second expansion, tenatively planned for 1985, will raise the base capacity to 15 MGD and the maximum capacity to 27 MGD. Two storage facilities are located at the plant. They consist of a reinforced concrete ground level clearwell with a capacity of one million gallons and an elevated washwater tank with a capacity of one hundred thousand gallons.

Treated water is pumped through a transmission main consisting of 79,500 feet of 24-inch diameter pipe and 35,000 feet of 16-inch diameter pipe by three high-service pumps with a maximum capacity of 9.5 MGD. A 900,000 gallon standpipe is located at the end of the transmission main in the western section of Fairfax City. Finished water storage facilities located within the distribution system include a 900,000 and a 4 MG tank in Fairfax city, a 1 MG tank in Sterling Park, Loundon County, and a 300,000 tank in Herndon. Wholesale water supplied to Loundon County, Herndon and FCWA is metered at several connection points along the 24-inch transmission main.

In addition to the water system facilties, the city operates and maintains collector sanitary sewers and trunk sewer lines within the city. Further wastewater conveyance and wastewater treatment are provided on a contractual basis with Fairfax County. Wastewater is treated at the Lower Potomac Treatment Plant in which the city owns 4.2 MGD of capacity.

DISTRICT OF COLUMBIA DEPARTMENT OF ENVIRONMENTAL SERVICES

The D.C. Department of Environmental Services, Water Resources Management Division, is responsible for the operation and maintenance of systems and facilities for the distribution of water, the control and disposal of storm water, and the collection, treatment and disposal of wastewater. Clientele served include residents, visitors and workers in the District of Columbia, and portions of surrounding Maryland and Virginia.

Treated water is obtained from the WAD of the U.S. Army Corps of Engineers from their Dalecarlia and McMillan Water Treatment Plants. The Dalecarlia Pumping Station with a capacity of 477 MGD draws water from Dalecarlia's 40 MGD clear well basins and delivers it to four service areas within the District; and through those areas, to metropolitan Maryland, to Arlington County, and to Falls Church, Virginia. The Bryant Street Pumping Station with a capacity of 310 MGD delivers McMillan water to four service areas within the District. The water distribution system maintained by the Department consists of an estimated 1400 miles of water mains, three water pumping stations, 10,000 fire hydrants, 27,500 valves, 130,000 service connections, and 8 water storage facilities. The Department also maintains, tests, and repairs 130,000 water meters to insure accurate consumption data.

In addition to the water distribution system, the D.C. Department of Environmental Services operates, maintains and repairs 1,800 miles of sanitary sewers and approximately 450 miles of storm sewers and their appurtenances; including over 28,000 catch basins, 600,000 manholes, 100 diversion structures and 50 gates. Also included in the wastewater collection system are 23 sewage pumping stations and several sewage screening stations. The Potomac Interceptor, which consists of 45 miles of sewer line serving the Dulles International Airport and adjacent areas in Maryland and Virginia, is also maintained by the District.

The largest wastewater treatment plant in the area, the Blue Plains Regional Wastewater Treatment Plant, is also maintained by the D.C.D.E.S. The plant has the capacity to provide complete treatment for 309 MGD of sanitary sewage, complete treatment for 41 MGD of flow from combined sewers, and primary treatment for 20 MGD of combined flow. Flows are received from the District of Columbia, and from portions of Maryland and Virginia including flow from the Potomac Interceptor. Pollutant removals are required as follows: 98 percent BOD removal, 98 percent suspended solids removal, 98 percent phosphorous removal, and 80 percent nitrogen removal.

ARLINGTON COUNTY DEPARTMENT OF PUBLIC WORKS

The Arlington County Department of Public Works is responsible for the operation of water distribution, wastewater collection, and wastewater treatment systems within Arlington County.

Treated water purchased from the WAD of the Corps of Engineers is the sole source of water for the county. Over 21 million gallons of water, all of which was treated at the Dalecarlia Water Treatment Plant, was purchased in FY 1980. The distribution system consists of approximately 435 miles of water mains and also includes 2,816 fire hydrants.

The Department of Public Works also maintains over 450 miles of sewer lines and operates and maintains the Arlington County Water Pollution Control Plant. The original primary treatment plant, built in 1933, had a capacity of 5 MGD. The plant was expanded in 1953 to a rated capacity of 20 MGD and was upgraded to secondary treatment and expanded again in 1968 for a total capacity of 24 MGD. An expansion to 30 MGD and the addition of advanced waste treatment facilities consisting of phosphorous, nitrogen, and carbon removal systems was initiated in 1973. The advanced wastewater treatment units are scheduled to go on line in the summer of 1981. In addition to the majority of Arlington County residents, the pollution control plant also serves some residents of Fairfax County, the City of Alexandria, and the City of Falls Church. Portions of Arlington County which are not served by the Arlington plant are served by the Blue Plains Regional Treatment Plant.

FALLS CHURCH DEPARTMENT OF PUBLIC UTILITIES

The Falls Church Department of Public Utilities has the responsibility of managing, operating, and maintaining the city's water and sewer systems. The Public Utilities Department buys treated water at wholesale rates from the WAD of the U.S. Army Corps of Engineers. Finished water is delivered via a transmission main consisting of 11,413 feet of 36-inch pipe from WAD's Dalecarlia Treatment Plant at MacArthur Boulevard to Langley, Virginia. A 24-inch connection to Arlington County's finished water supply main at Chain Bridge is kept intact for emergency uses. Falls Church also purchases a small amount of water from Arlington County to serve approximately 200 homes, which are located in an area too high to be served from the Falls Church system, and has emergency connections with the Fairfax County Water Authority. The city provides water on a wholesale basis to the Town of Vienna, Fairfax County Water Authority and Arlington County. The city can also sell water to Fairfax City for emergency uses through a 6-inch connection at Fairfax Circle.

As of 1979, the distribution system, which was aquired by the purchase of three private water companies and supplemented by construction, contains approximately 370 miles of water lines. At the present ime, Falls Church has nine water storage tanks with total storage capacity of 11 MG. The storage facilities are equipped with telemetering units which report the water level via tone system to the central control office at the Chesterbrook Pumping Station. The Chesterbrook Pumping Station is the main station of a total of seven stations, which have a combined capacity of 59.2 MGD. Each station can be operated automatically or manually from the station or from Chesterbrook. Information from the stations is reported to Chesterbrook by telemetering units via tone system.

The Public Utilities Department provides sewerage service for the residents of the city and approximately 361 homes adjacent to the city's boundaries. As of 1970, the sewage collection system included 105,396 feet of sewer pipe and 842 manholes. Wastewater is transported beyond the City's boundaries and is treated by either Arlington County Department of Public Works or Fairfax County Department of Public Works under contract. Approximately two-thirds of the sewage is treated by Fairfax County Department of Public Works at the Alexandria Wastewater Treatment Plant, and the other one-third treated by Arlington County Department of Public Works at their Water Pollution Control Plant. Total wastewater flow from Falls Church in 1980 was approximately 584 MG.

VIENNA DEPARTMENT OF PUBLIC WORKS

The town of Vienna, Department of Public Works provides water and sewerage services to town residents. The water distribution and portions of the sewage collection systems are operated and maintained by the Public Works Department. Water supply and wastewater disposal services are currently provided by surrounding jurisdictions on a contractual basis.

Treated water is purchased from Falls Church, who in turn purchases water from the WAD of the U.S. Corp of Engineers. Approximately 728 MG were purchased in 1979-1980 through connections at Wall Street and Vale Road in Falls Church.

Wastewater disposal and treatment are provided through contracts with the District of Columbia and Fairfax County.. Roughly 1 MGD or about half of the wastewater flow generated in Vienna is conveyed through the Potomac Interceptor to the Blue Plains Regional Wastewater Treatment Plant operated by the D.C. Department of Environmental Services. The other half is conveyed through the Accotink Sewer to the Lower Potomac Wastewater Treatment Plant operated by the Fairfax County Department of Public Works.

FAIRFAX COUNTY DEPARTMENT OF PUBLIC WORKS

The Fairfax County Department of Public Works is the responsible agency for wastewater collection and disposal activities within Fairfax County. Several jurisdictions within Fairfax County also utilize facilities operated and maintained by the Department of Public Works.

As of FY 1980, approximately 1,926 miles of gravity sewers and 9.4 miles of forcemains were maintained by the Public Works Department. The bulk of wastewater generated in Fairfax County is presently delivered to one of seven wastewater treatment plants including Blue Plains, Arlington, Lower Potomac, Little Hunting Creek, Douge Creek, Alexandria, and UOSA Treatment Plants. Plants operated and maintained by Fairfax County include the Lower Potomac, Little Hunting Creek, and Douge Creek. Douge Creek and Little Hunting Creek flows are scheduled to be switched over to the Lower Potomac, and the plants are to be taken off line within the next year for Douge Creek and within the next 8-10 years for Little Hunting Creek.

ALEXANDRIA SANITATION AUTHORITY

The Alexandria Sanitation Authority, an independent public agency, provides wastewater collection and disposal services for most of the City of Alexandria and neighboring portions of Fairfax County, specifically the Cameron Run and Lower Four Mile Run Watersheds. Laterals, minor trunk lines and certain relief stations used for sewage collections are the responsibility of the Alexandria City Department of Public Works.

Principal facilities operated and maintained by the Sanitation Authority include approximately 12 miles of 30-inch to 72-inch interceptor sewers and the Alexandria Wastewater Treatment Plant. The original secondary plant completed in 1956, had a design capacity of 18 MGD and included preliminary treatment facilities (bar screen, mechanical screen, and grit chamber) and secondary treatment facilities consisting of trickling filters, secondary sedimentation basins, chlorination basins, and two-stage anaerobic digestion facilities for sludge handling. The preliminary and primary facilities have since been expanded and the trickling filters replaced with rotating biological contacters to a current capacity of 54 MGD. Advanced wastewater treatment facilities consisting of granular carbon columns, phosphorous removal facilities with chemical recovery, and dual media filters have also been recently added to the plant.

APPENDIX C

COST FORECASTS FOR POTOMAC DEPENDENT UTILITIES

The cost data development work reported in Appendix B contained some errors due to miscommunications between engineer and economist. Therefore the data tables were deleted from the excerpts of the engineering report presented in Appendix B. The correct cost forecasts are tabulated in Appendix C.

The tabulation presents: average cost forecasts at 100 MGD and 300 MGD levels of flow-by; long- and short-run marginal cost forecasts for wastewater; and long-and short-run marginal cost forecasts for water at both 100 MGD and 300 MGD levels of flow-by.

	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030
AC @ 100	186.2	201.6	233.7	244.9	253.3	256.4	261.6	268.4	268.5	268.2	270.5
AC @ 300	187.2	202.6	233.7	244.9	257.3	260.4	265.6	272.4	272.5	271.2	273.5
WW LRMC	23.1	27.3	41.3	43.5	45.9	46.4	48.2	54.3	54.4	54.4	55.0
WW SRMC	26.5	30.5	33.7	36.2	37.7	38.2	38.2	38.2	38.2	38.2	38.2
Water LRMC @ 100	40.5	42.3	45.9	49.9	50.7	51.5	53.5	53.5	53.5	53.5	53.5
Water SRMC @ 100	11.4	13.0	14.5	15.6	16.4	16.4	16.4	16.4	16.4	16.4	16.4
Water LRMC @ 300	40.6	42.4	46.0	50.0	60.1	60.9	61.7	61.7	61.7	61.7	61.7
Water SRMC @ 300	11.4	13.0	14.5	15.6	26.4	26.4	26.4	26.4	26.4	26.4	26.4

Exhibit C-1: AC, SRMC, AND LRMC FORECASTS: FAIRFAX COUNTY
(¢/1000 gal)

	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030
AC @ 100	193.8	216.1	229.8	240.9	255.0	257.7	258.2	263.9	263.9	263.9	264.0
AC @ 300	194.8	217.1	229.8	240.9	259.0	261.7	262.2	267.9	267.9	266.9	267.0
WW LRMC	27.7	47.2	48.6	55.5	58.3	58.4	60.4	60.7	60.7	60.7	60.7
WW SRMC	15.6	17.9	19.8	21.3	22.2	22.5	22.5	22.5	22.5	22.5	22.5
Water LRMC @ 100	31.0	31.6	32.2	32.7	33.1	37.6	38.8	38.8	38.8	38.8	38.8
Water SRMC @ 100	7.4	8.6	9.4	10.2	10.6	10.6	10.6	10.6	10.6	10.6	10.6
Water LRMC @ 300	31.1	31.7	32.3	32.8	42.5	47.0	47.0	47.0	47.0	47.0	47.0
Water SRMC @ 300	7.4	8.6	9.4	10.2	20.6	20.6	20.6	20.6	20.6	20.6	20.6

Exhibit C-2: AC, SRMC, AND LRMC FORECASTS: WSSC
(¢/1000 gal)

	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030
AC @ 100	155.5	172.0	184.0	201.0	206.5	208.3	208.3	223.7	223.7	223.7	223.7
AC @ 300	156.5	173.0	184.0	201.0	210.5	212.3	212.3	227.7	227.7	226.7	226.7
WW LRMC	23.8	25.0	25.8	40.8	41.2	41.4	41.4	64.6	64.6	64.6	64.6
WW SRMC	20.5	23.6	26.1	28.0	29.2	29.5	29.5	29.5	29.5	29.5	29.5
Water LRMC @ 100	16.9	20.3	20.9	21.3	21.5	21.5	22.7	22.7	22.7	22.7	22.7
Water SRMC @ 100	10.3	11.8	13.1	14.1	14.7	14.9	14.9	14.9	14.9	14.9	14.9
Water LRMC @ 300	17.0	20.4	21.0	21.4	30.9	30.9	30.9	30.9	30.9	30.9	30.9
Water SRMC @ 300	10.3	11.8	13.1	14.1	24.7	24.9	24.9	24.9	24.9	24.9	24.9

Exhibit C-3: AC, SRMC, AND LRMC FORECASTS: FALLS CHURCH
(¢/1000 gal)

	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030
AC @ 100	118.9	138.1	147.6	154.5	165.4	166.6	166.6	172.5	172.5	172.5	172.5
AC @ 300	119.9	139.1	147.6	154.5	169.4	170.6	170.6	176.5	176.5	175.5	175.5
WW LRMC	21.6	46.4	47.4	48.0	55.5	55.6	55.6	56.0	56.0	56.0	56.0
WW SRMC	13.5	15.5	17.2	18.4	19.2	19.5	19.5	19.5	19.5	19.5	19.5
Water LRMC @ 100	14.6	17.7	18.2	18.3	18.6	18.6	19.8	19.8	19.8	19.8	19.8
Water SRMC @ 100	10.2	11.7	13.0	13.9	14.5	14.7	14.7	14.7	14.7	14.7	14.7
Water LRMC @ 300	14.7	17.8	18.3	18.4	28.0	28.0	28.0	28.0	28.0	28.0	28.0
Water SRMC @ 300	10.2	11.7	13.0	13.9	24.5	24.7	24.7	24.7	24.7	24.7	24.7

Exhibit C-4: AC, SRMC, AND LRMC FORECASTS: D.C.
(¢/1000 gal)

	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030
AC @ 100	229.5	254.5	273.4	307.5	317.7	319.8	319.8	319.8	319.8	319.8	319.8
AC @ 300	230.5	255.5	273.4	307.5	321.7	323.8	323.8	323.8	323.8	322.8	322.8
WW LRMC	43.1	48.0	50.4	92.0	93.6	94.0	94.0	94.0	94.0	94.0	94.0
WW SRMC	42.0	48.3	53.4	57.3	59.8	60.6	60.6	60.6	60.6	60.6	60.6
Water LRMC @ 100	16.1	19.4	19.8	20.2	20.3	20.5	21.7	21.7	21.7	21.7	21.7
Water SRMC @ 100	9.3	10.7	11.8	12.7	13.3	13.4	13.4	13.4	13.4	13.4	13.4
Water LRMC @ 300	16.2	19.5	19.9	20.3	29.7	29.9	29.9	29.9	29.9	29.9	29.9
Water SRMC @ 300	9.3	10.7	11.8	12.7	23.3	23.4	23.4	23.4	23.4	23.4	23.4

Exhibit C-5: AC, SRMC, AND LRMC FORECASTS: ARLINGTON
(¢/1000 gal)

	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030
AC @ 100	203.7	223.9	233.8	247.7	282.3	284.1	284.2	284.2	284.2	284.2	284.2
AC @ 300	204.7	224.9	233.8	247.7	286.3	288.1	288.2	288.2	288.2	287.2	287.2
WW LRMC	25.1	26.3	27.4	32.3	32.9	32.9	32.9	64.4	64.4	64.4	64.4
WW SRMC	17.8	20.4	22.7	24.3	25.4	25.7	25.7	25.7	25.7	25.7	25.7
Water LRMC @ 100	27.9	28.5	29.0	31.9	32.3	32.3	33.5	33.5	33.5	33.5	33.5
Water SRMC @ 100	8.0	9.2	10.1	10.9	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Water LRMC @ 300	28.0	28.6	29.1	32.0	41.7	41.7	41.7	41.7	41.7	41.7	41.7
Water SRMC @ 300	8.0	9.2	10.1	10.9	21.5	21.5	21.5	21.5	21.5	21.5	21.5

Exhibit C-6: AC, SRMC, AND LRMC FORECASTS: ALEXANDRIA
(¢/1000 gal)

	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030
AC @ 100	207.5	235.4	252.9	266.0	281.2	284.5	284.5	293.4	293.4	293.4	293.4
AC @ 300	208.5	236.4	252.9	266.0	285.2	288.5	288.5	297.4	297.4	296.4	296.4
WW LRMC	21.3	46.2	47.0	47.6	55.1	55.2	55.2	55.6	55.6	55.6	55.6
WW SRMC	23.2	26.7	29.5	31.7	33.0	34.4	34.4	34.4	34.4	34.4	34.4
Water LRMC @ 100	23.0	24.1	25.0	25.8	26.3	26.5	27.7	27.7	27.7	27.7	27.7
Water SRMC @ 100	14.6	16.8	18.6	19.9	20.9	21.1	21.1	21.1	21.1	21.1	21.1
Water LRMC @ 300	23.1	24.2	25.1	25.9	35.7	35.9	35.9	35.9	35.9	35.9	35.9
Water SRMC @ 300	14.6	16.8	18.6	19.9	30.9	31.1	31.1	31.1	31.1	31.1	31.1

Exhibit C-7: AC, SRMC, AND LRMC FORECASTS: ROCKVILLE
(¢/1000 gal)

	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030
AC @ 100	206.8	233.0	262.4	275.9	287.2	289.6	296.9	299.6	299.6	299.6	299.6
AC @ 300	207.8	234.0	262.4	275.9	291.2	293.6	300.9	303.6	303.6	302.6	302.6
WW LRMC	40.3	55.1	57.3	78.5	83.0	83.3	83.3	83.5	84.3	84.3	84.3
WW SRMC	37.4	42.9	47.6	51.1	53.2	53.9	53.9	53.9	53.9	53.9	53.9
Water LRMC @ 100	14.6	17.9	18.5	18.7	18:9	18.9	20.1	20.1	20.1	20.1	20.1
Water SRMC @ 100	9.5	10.9	12.1	13.0	13.5	13.7	13.7	13.7	13.7	13.7	13.7
Water LRMC @ 300	14.7	18.0	18.6	18.8	28.3	28.3	28.3	28.3	28.3	28.3	28.3
Water SRMC @ 300	9.5	10.9	12.1	13.0	23.5	23.7	23.7	23.7	23.7	23.7	23.7

Exhibit C-8: AC, SRMC AND LRMC FORECASTS: VIENNA
(¢/1000 gal)

	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030
AC @ 100	175.2	228.0	241.7	250.7	257.5	258.9	258.5	258.5	268.3	268.3	268.3
AC @ 300	176.2	229.0	241.7	250.7	261.5	262.9	262.5	262.5	272.3	271.3	271.3
WW LRMC	19.3	53.9	55.3	56.4	57.1	57.3	57.3	64.5	64.5	64.5	64.5
WW SRMC	16.5	19.0	21.0	22.6	23.5	23.8	23.8	23.8	23.8	23.8	23.8
Water LRMC @ 100	34.8	36.0	36.8	40.4	41.0	41.1	43.1	43.1	43.1	43.1	43.1
Water SRMC @ 100	10.6	12.1	13.5	14.5	15.1	15.3	15.3	15.3	15.3	15.3	15.3
Water LRMC @ 300	34.9	36.1	36.9	40.5	50.4	50.5	51.3	51.3	51.3	51.3	51.3
Water SRMC @ 300	10.6	12.1	13.5	14.5	25.1	25.3	25.3	25.3	25.3	25.3	25.3

Exhibit C-9: AC, SRMC, AND LRMC FORECASTS: DALE CITY
(¢/1000 gal)

	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030
AC @ 100	300.9	326.8	350.2	363.3	373.6	376.2	375.8	375.8	375.8	383.5	383.5
AC @ 300	301.9	327.8	350.2	363.3	377.6	380.2	379.8	379.8	379.8	386.5	386.5
WW LRMC	43.2	44.7	45.9	46.7	47.2	47.5	47.5	47.5	47.5	55.1	55.1
WW SRMC	34.6	39.8	46.0	47.3	49.3	49.6	49.6	49.6	49.6	49.6	49.6
Water LRMC @ 100	33.6	34.7	35.5	39.0	39.5	39.6	41.6	41.6	41.6	41.6	41.6
Water SRMC @ 100	12.4	14.3	15.7	16.9	17.6	17.9	17.9	17.9	17.9	17.9	17.9
Water LRMC @ 300	33.7	34.8	35.6	39.1	48.9	49.0	49.8	49.8	49.8	49.8	49.8
Water SRMC @ 300	12.4	14.3	15.7	16.9	27.6	27.9	27.9	27.9	27.9	27.9	27.9

Exhibit C-10: AC, SRMC, AND LRMC FORECASTS: OWDT
(¢/1000 gal)

APPENDIX D

OTHER UTILITIES NOT DRAWING FROM THE POTOMAC

In addition to the major Potomac-dependent utilities, which are the principal subject of this report, the Corps of Engineers expanded the scope of study to include a quick canvass of 12 smaller utilities in outlying areas of the Metropolitan Washington Area which draw water from sources other than the Potomac. This task was conducted largely by telephone survey and was originally intended to be a qualitative analysis of a sampling of these utilities. It was later found to be feasible to cover all 12 with quantitative detail. However, the quality of the estimates may not be as good as that for the Potomac utilities in certain respects. The results of this effort are summarized in this appendix. The theoretical framework and the analytical methodologies employed are the same as those described in the body of the report for the Potomac-dependent utilities.

The most popular rates among non-Potomac users are uniform rates and block rates. In both types, the average price often tends to approximate average cost. This is illustrated in Exhibit D-1. There are, however, more scatter points evident in this diagram than in the comparable figure for the Potomac users. To some extent this may be due to error in cost estimates. It is suspected that some small town utilities did not report all utility costs because local government services are used but not attributed to the utility. On the other hand, there are a number of instances in which the utility is regarded as a revenue generating enterprise for the local government, producing excessively high rates.

The average cost forecasts for the non-Potomac utilites are summarized in Exhibit D-2. Exhibit D-3 shows the proportion of total cost that is categorized as fixed cost. For these non-Potomac utilities the average proportion of fixed costs in 38%. This is roughly the same level as for the Potomac users and has the effect of keeping marginal cost peak period rates below rates from present pricing.

Exhibits D-4 through D-7 present the long- and short-run marginal cost forecasts for the non-Potomac utilities. It is notable that they exhibit relatively little escalation in the long-run marginal cost of water. In most cases, this is due to the presence of high quality well water. This low cost supply source diminishes the effectiveness of pricing

for these utilities for the same reason that supply management reduces the value of pricing for Potomac users; avoidable costs are not as great. At some point in the future, the Drinking Water Act or similar imperative could put a sharp spike into these cost curves. However, every one of the 12 utilities interviewed denied having any expectations of major cost increases due to compliance with the Drinking Water Act. Absence of trace contaminants in well water supplies is most often given as the explanation.

Exhibits D-8 through D-19 present the results of comparing present rates of these utilities with marginal cost peak period rates. Of all twelve non-Potomac-dependent utilities, only the City of Manassas shows a peak quarter rate above average cost. The peak rate does not exceed the current price, however. The City of Manassas is quite different from most of the other outlying small utilities in that lake water is the supply source instead of well water. Wells are much cheaper sources because, in most of the outlying utilities, well water requires little or no treatment. In contrast, the City of Manassas operates a fairly sophisticated water treatment plant. It is also noted that the City of Manassas provided some of the most detailed input data of all of the outlying utilities. This might have contributed to a higher estimate of variable costs.

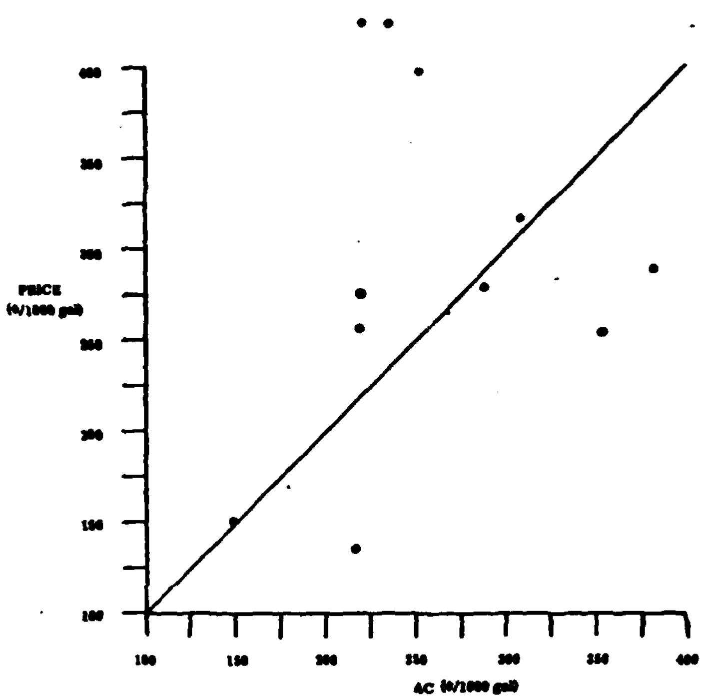


Exhibit D-1: PRESENT PRICE VS. AVERAGE COST
(Non-Potomac Users)

D-3

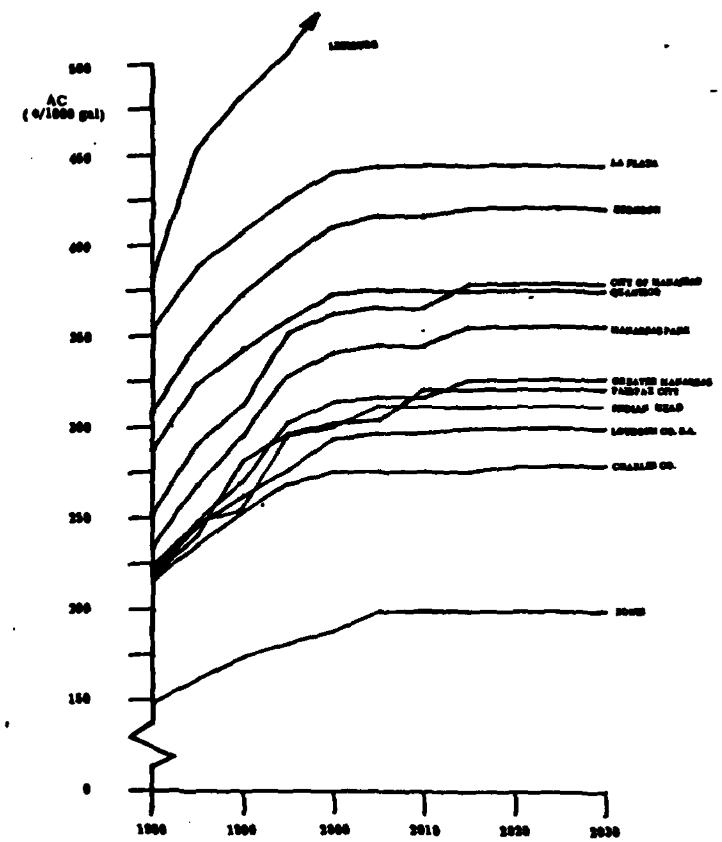


Exhibit D-2: AVERAGE COST PROJECTIONS
(Non-Potomac Users)

D-4

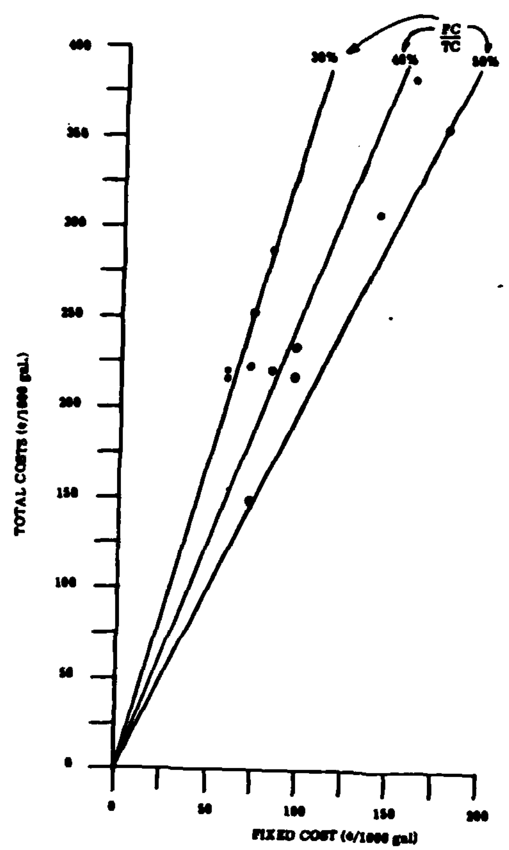


Exhibit D-3: FIXED COSTS AS A PROPORTION OF TOTAL COSTS
(Non-Potomac Users)

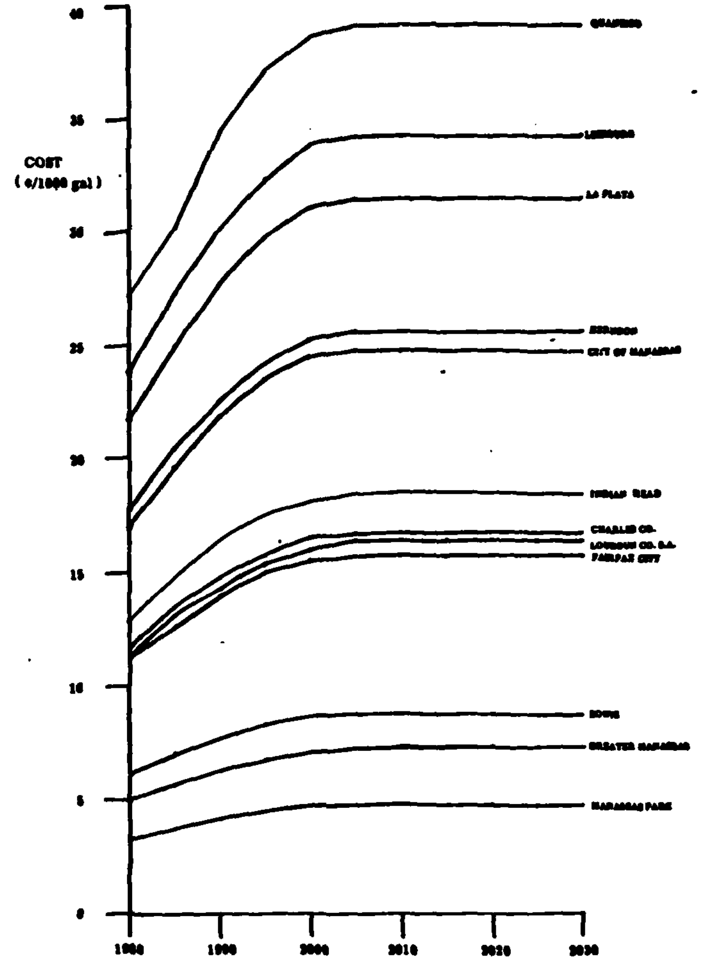


Exhibit D-4: WATER SHORT-RUN MARGINAL COST FORECAST
(Non-Potomac Users)

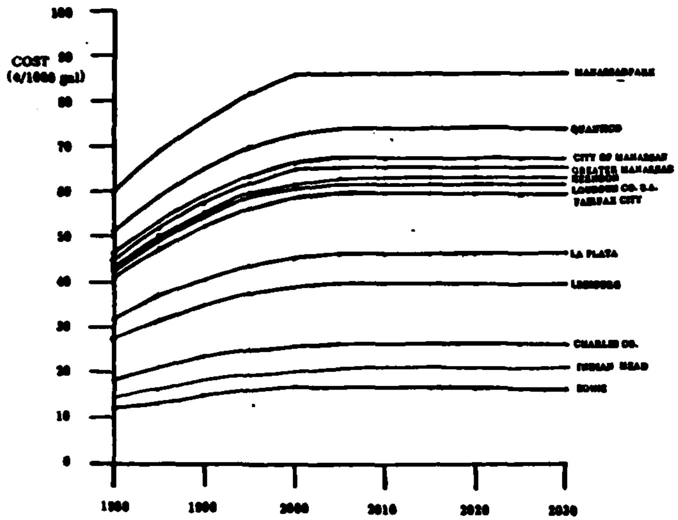


Exhibit D-5: WASTEWATER SHORT-RUN MARGINAL COST FORECAST
(Non-Potomac Users)

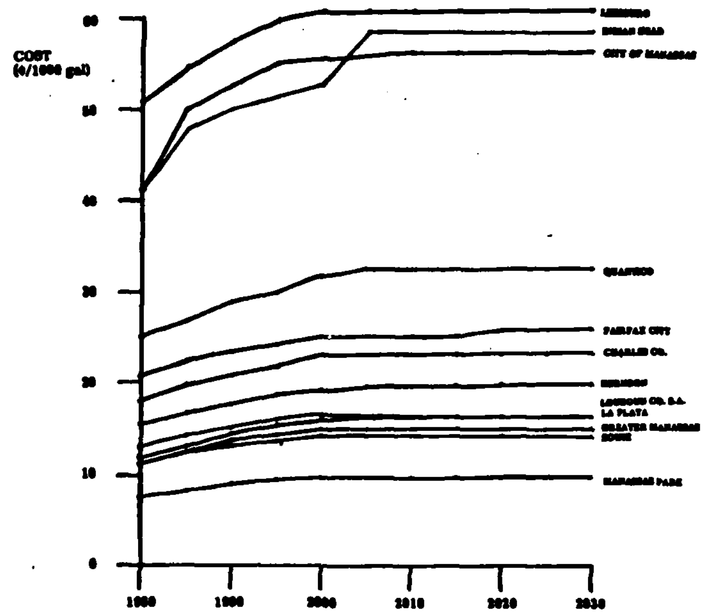


Exhibit D-6: WATER LONG-RUN MARGINAL COST FORECAST
(Non-Potomac Users)

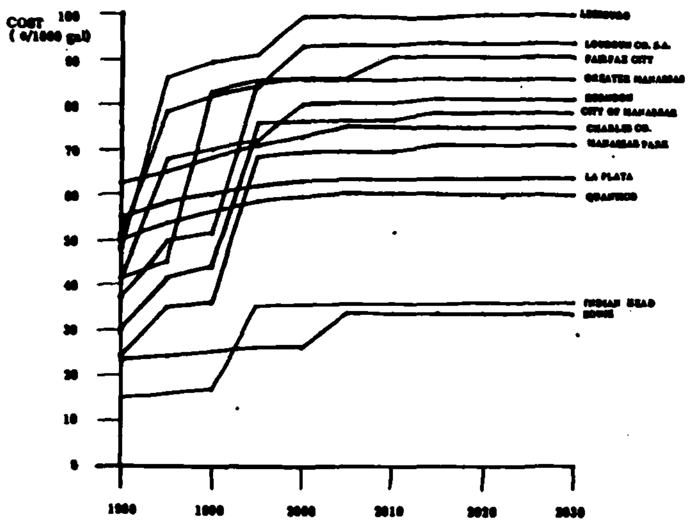


Exhibit D-7: WASTEWATER LONG-RUN MARGINAL COST FORECAST
(Non-Potomac Users)

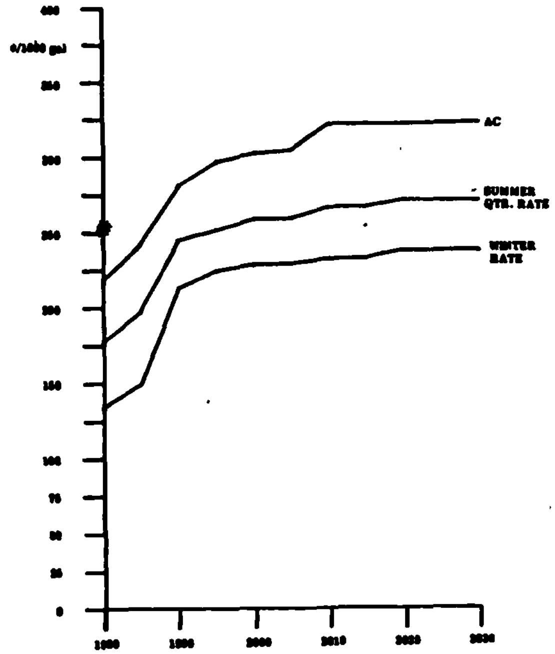


Exhibit D-8: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: FAIRFAX CITY

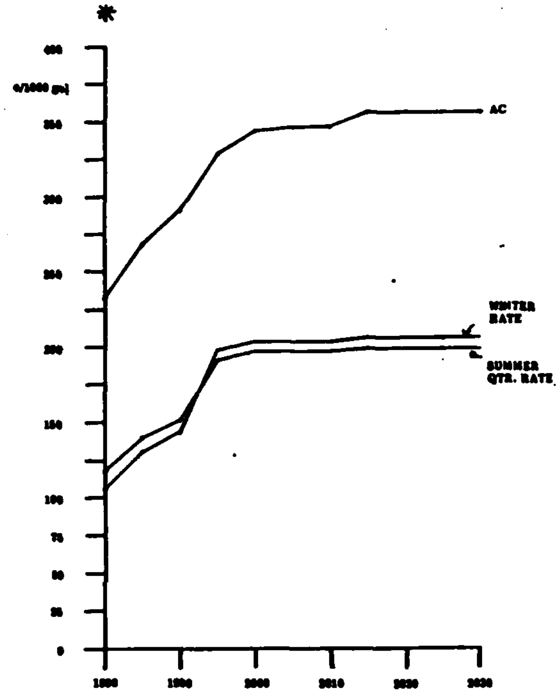


Exhibit D-9: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: CITY OF MANASSAS PARK

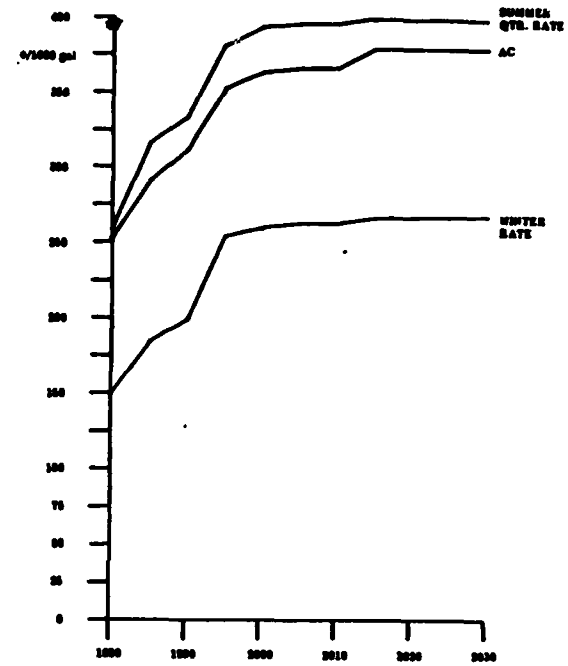


Exhibit D-10: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: CITY OF MANASSAS

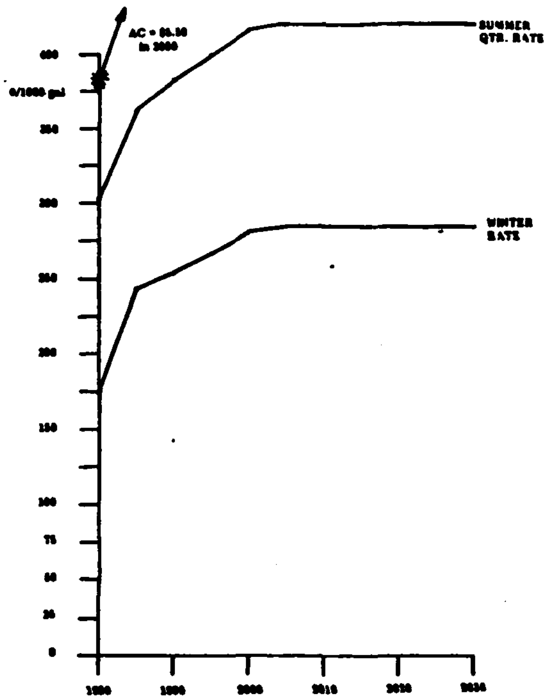


Exhibit D-11: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES:
LEESBURG

D-13

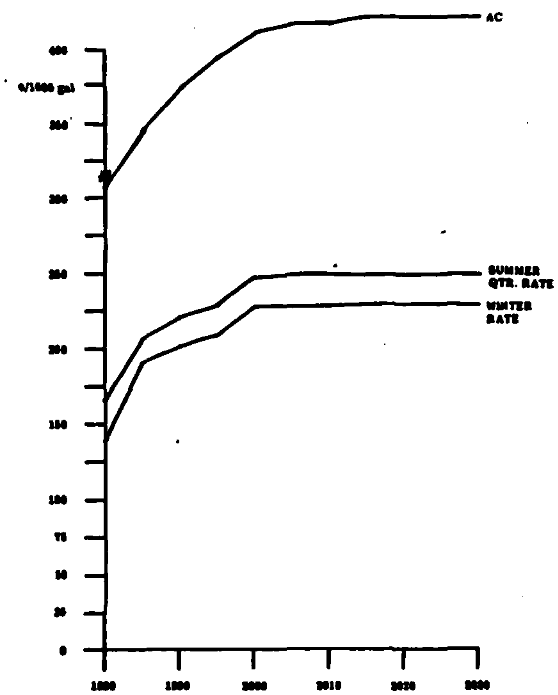


Exhibit D-12: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES:
HERNDON

D-14

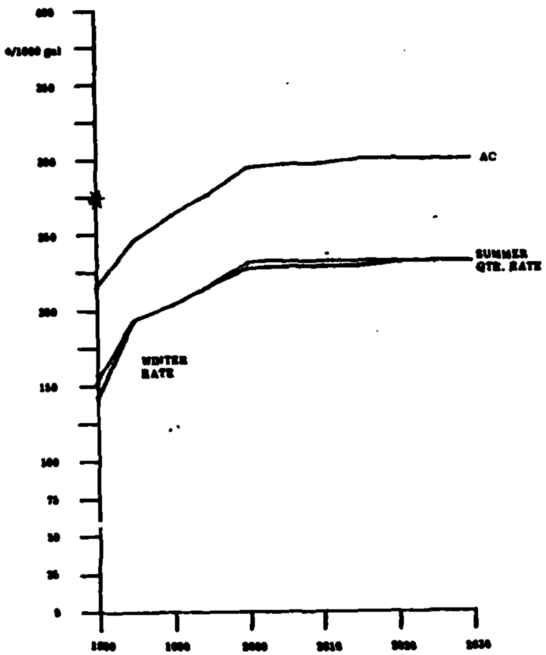


Exhibit D-13: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: LOUDOUN COUNTY

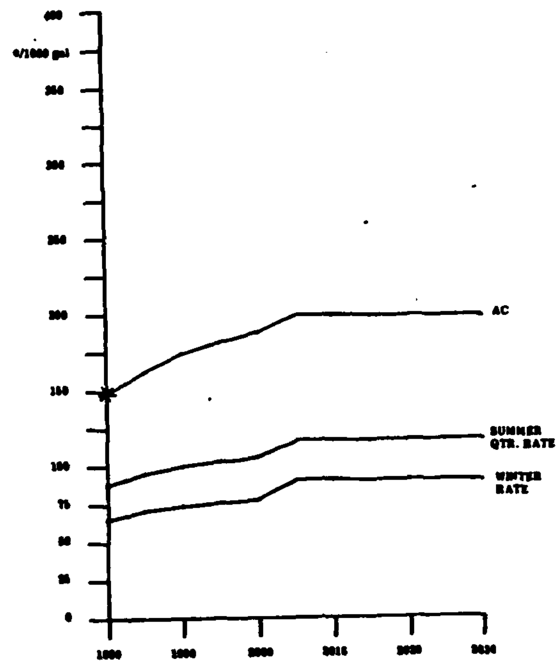


Exhibit D-14: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: BOWIE

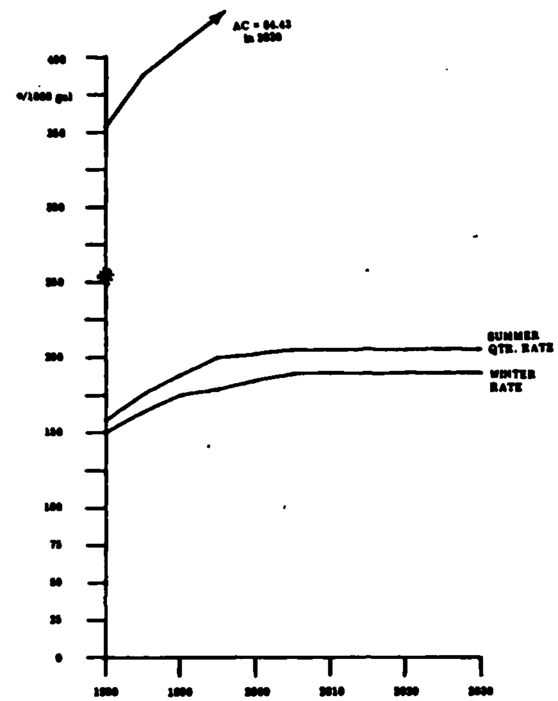


Exhibit D-15: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: LA PLATA

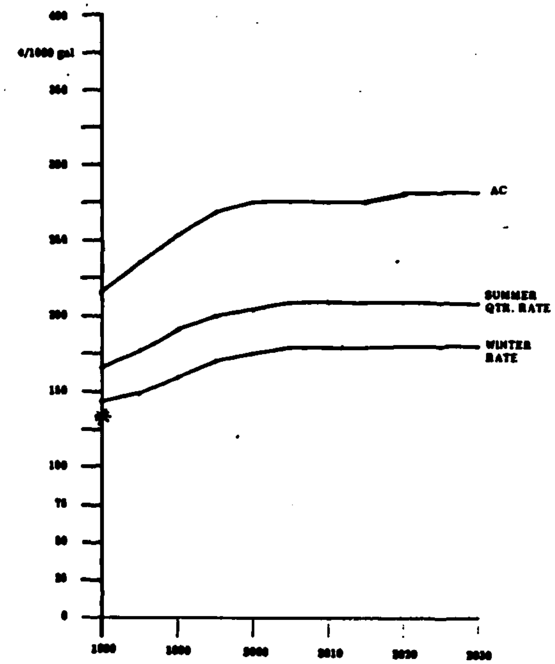


Exhibit D-16: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: CHARLES COUNTY

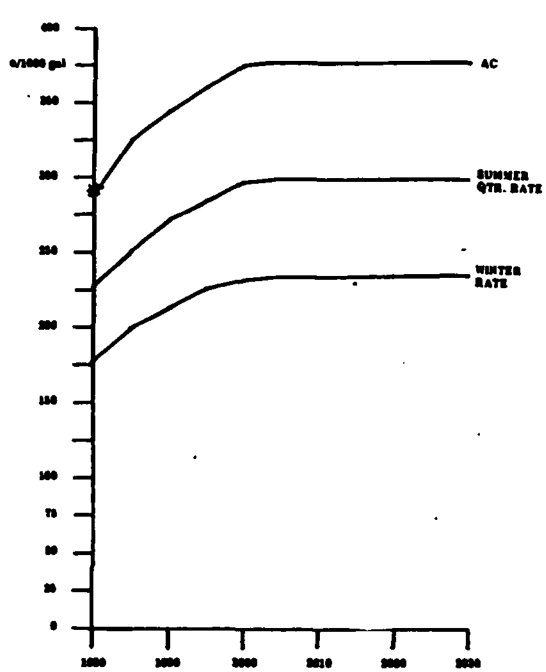


Exhibit D-17: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: QUANTICO

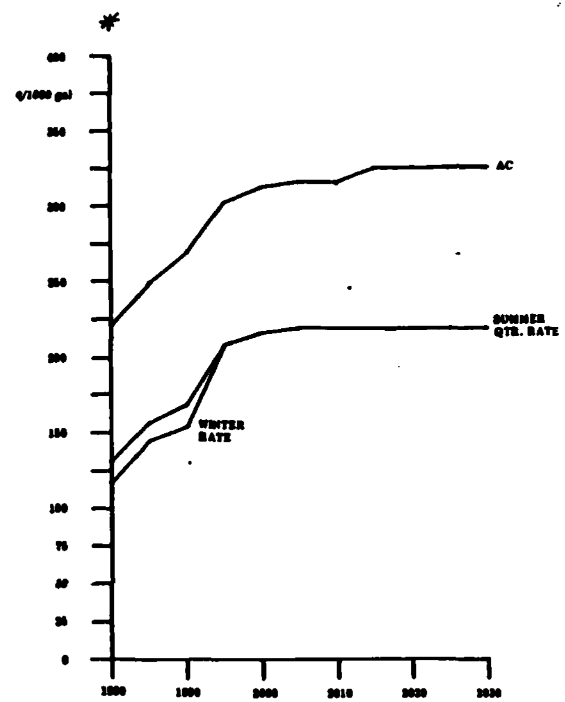


Exhibit D-18: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: GREATER MANASSAS SANITARY DISTRICT

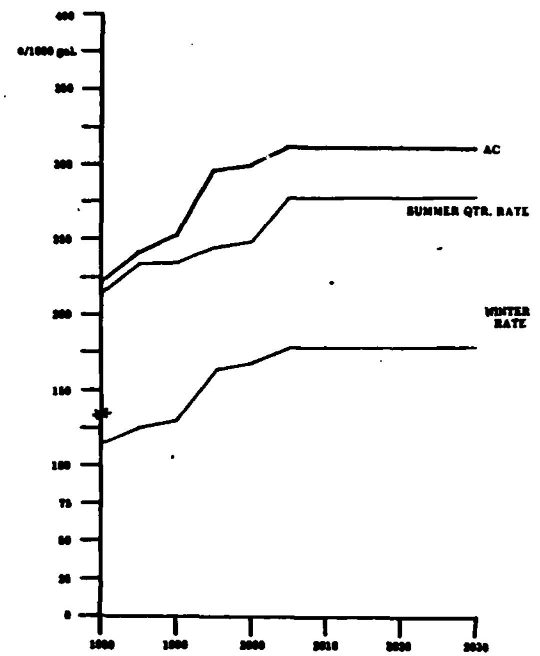


Exhibit D-19: EXISTING RATES VS. MARGINAL COST PEAK PERIOD RATES: INDIAN HEAD

REFERENCES

(1) Potomac River Basin Study, 1970, U.S. Army Corps of Engineers, Baltimore District.

(2) Potomac River Basin Water Supply - An Interim Report, 1973, U.S. Army Corps of Engineers, Baltimore District.

(3) Northeastern United States Water Supply (NEWS) Study, 1975, U.S. Army Corps of Engineers, North Atlantic Division and Baltimore District.

(4) Draft Progress Report on the Metropolitan Washington Area Water Supply Study, 1979, U.S. Army Corps of Engineers, Baltimore District.

(5) Water for the Future of the National Capital Area, National Research Council, Academy of Engineering, Committee to Review the Metropolitan Washington Area Water Supply Study, 1980.

(6) The Evaluation of Water Conservation for Municipal and Industrial Water Supply, Volume II: Illustrative Examples, 1980, U.S. Army Engineer Institute for Water Resources.

(7) Price As A Water Utility Management Tool Under Stochastic Conditions, Carver, P.H., unpublished Ph.D. thesis, Department of Geography and Environmental Engineering, the Johns Hopkins University, 1978.

(8) Analysis of the Economics of Water Supply in the Washington Metropolitan Area, 1980, U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Drinking Water Research Division.

(9) "Interest Rates and Price Level Changes, 1952-69," Federal Reserve Board of St. Louis, Review, December 1969, 51, 18-38, Yoke, W.P. and D.S. Karnovsky.

(10) "Interest Rates and Expected Inflation: A Selective Summary of Recent Literature," Nat. Bureau of Econ. Res., Exploration in Economic Research, No. 3, 1976, Sargent, T.J.

(11) "Inflation and the Stock Market" Am. Econ. Review, December 1980, Feldstein, M.S.

(12) "Risk, The Winners' Curse, and Taxes: Exant vs. Export Yields on OCS Investment," paper delivered at the AEA Meeting, Denver, Colorado, 6 September 1980, Ott, Mark.

(13) Quarterly Financial Reports for Manufacturing Corporations, Washington, D.C., U.S. Federal Trade Commission.

(14) Report on Tennessee-Tombigbee Waterway, Committee on Appropriations, Subcommittee on Energy and Water Development, September 1980, p. 7.

(15) U.S. HEW, Unpublished study by Harvard University in which carrying cost of real dollars was required for analysis.

(16) "Procedure for Evaluation of National Economic Development (NED) Benefits and Costs in Water Resources Planning, (Level C) Final Rule," and "Principles and Standards for Planning Water and Related Land Resources," 44 Fed. Reg. 72892, et seq., December 14, 1979, U.S. Water Resources Council.

(17) "An Economists View of Demand Projections Considering Conservation," Water Resources Bull., October 1980, pp. 941-943, Morgan, W.D.

(18) "Comment on the Price Elasticity of Demand for Municipal Water: A Case Study of Tuscon, Arizona by Robert A. Young," Colander, D.C., and John C. Haltiwanger.

(19) "The Impact of Price on Residential Water Demand and its Relation to System Design and Price Structure," Water Resource Res., 3:13-32, 1967, Howe, C.W., and F.P. Linaweaver, Jr.

(20) "Systems Analysis for Wastewater Reuse. A Methodology for Municipal Water Supply Planning in Water-Short Metropolitan Areas," A report of the Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C., July, 1977, Milliken, J.G., et al.

(21) "Residential Water Demand: The Case from Micro Data," Water Resources Research, August, 1973, Morgan, W.D.

(22) "Short and Long Run Effects of Price on Municipal Water Use," Water Resources Research, Volume 16, Number 4, pp 609-616, August, 1980, Carver, P.H. and J.J. Boland.

(23) University of Pennsylvania, Study for WSSC; private conversation with the Pennsylvania State authors concerning elasticity of demand estimates.

OTHER LITERATURE CONSULTED

(1) Balestra, P., and M. Nerlove, "Pooling Cross Section and Time Series Data in the Estimation of a Dynamic Model: The Demand for Natural Gas," Econometrica, 34:585-612, 1966.

(2) Baumann, Duane D., et al. "The Role of Conservation in Water Supply Planning," A report to the U.S. Army Engineer Institute for Water Resources, Fort Belvoir, VA, April 1979.

(3) Boland, J., S.H. Hanke, R.L. Church, and P.H. Carver, "An Examination of Alternate Rate-Making Policies for the Washington Suburban Sanitary Commission." Rivus, Inc., Baltimore, MD, 1975.

(4) Boland, J.J., et al., "How Much Water Supply Capacity is Enough?" Journal AWWA, July 1980.

(5) Boland, J.J., S.H. Hanke, and R.L. Church, "An Assessment of Rate-Making Policy: Alternatives for Washington Suburban Sanitation Commission," September, 1972.

(6) Bonem, G.W., "On the Marginal Cost Pricing of Municipal Water," Water Resources Research, Volume 4, Number 1, February, 1968.

(7) Camp, R.C., "The Inelastic Demand for Residential Water: New Findings," J. Amer. Water Works Assoc., 70:453-458, 1978.

(8) Carey, D.L., and C.T. Haan, "Conservational Water Pricing For Increased Water Supply Benefits," Water Resources Bulletin, Volume 12, Number 6, December, 1976.

(9) Carns, K.E., and D.C. Larkin, "Water District Revenue Implications of Conservation," from The Proceedings for the Water Conservation Conference, Rindge, New Hampshire, July 1979.

(10) Clark, R.M., "Cost and Pricing Relationships in Water Supply," Journal of the Environmental Engineering Division, Proceedings of the A.S.C.E., Volume 102, EE2, April, 1976.

(11) Clark, R.M. and H.C. Goddard, Pricing for Water Supply, Its Impact on Systems Management", A report to the National Environmental Resource Center, Cincinnati, Ohio, April, 1974.

(12) Crew, M.A., and G. Roberts, "Some Problems of Pricing under Stochastic Supply Conditions: The Case of Seasonal Pricing for Water Supply," Water Resources Research, Volume 6, Number 5, October, 1970.

(13) Crews, J.E. and W.E. Trieschman, "Drought Effects on Metropolitan, Washington, D.C. Area," from The Proceedings for the Water Conservation Conference, Rindge, New Hampshire, July, 1979.

(14) Davis, R.K., and S.H. Kanke, "Conventional and Unconventional Alternatives for Water Supply Management," Water Resources Research, Volume 9, Number 4, August, 1973.

(15) Ecological Analysts, Inc. "Water Supply Study for Montgomery and Prince Georges Counties, Md." Prepared for Bicounty Water Supply Task Force and Washington Suburban Sanitary Commission, October 1977.

(16) Foster, H.S. and B.R. Beattie, "Urban Residential Demand for Water in the United States," Land Economics, February, 1979.

(17) Griffith, F.P., "An Innovative Approach to Rate-Making," J. Amer. Water Works Assoc. 69:89-91, 1977.

(18) Griffith, F.P., "An Equitable Rate Structure's Relation to Conservation and Wastewater Flow Reduction," Fairfax County Water Authority, 1978.

(19) Gysi, M., "A Simulation of the Effects of Dynamic Water Pricing Policies," Report to the Office of Water Resources Research, Department of the Interior, June, 1972.

(20) Hanke, S.H., and J.E. Flack, "Effects of Metering Urban Water," Journal AWWA, December, 1968.

(21) Hanke, S.H., and R.K. Davis, "Potential for Marginal Cost Pricing in Water Resource Management," Water Resources Research, Volume 9, Number 4, August, 1973.

(22) Hanke, S.H. "Demand for Water under Dynamic Conditions," Water Resources Research, October, 1970.

(23) Hanke, S.H., "Some Behavioral Characteristics Associated with Residential Water Price Changes," Water Resources Research, Volume 6, Number 5, October, 1970.

(24) Hanke, S.H., "Water Rates: An Assessment of Current Issues," Journal AWWA, May, 1975.

(25) Hanke, S.H., and R.K. Davis, "Demand Management Through Responsive Pricing," Journal AWWA, Volume 63, Number 9, September, 1971.

(26) Hogarty, T.F., and R.J. Mackay, "The Impact of Large Temporary Rate Changes on Residential Water Use," Water Resources Research, Volume II, Number 6, December, 1975.

(27) Hollman, K.W., and W.J. Primeaux, Jr., "The Effect of Price and Other Selected Variables on Water Consumption," Mississippi State University, 1973.

(28) Howe, C.W., "Water Pricing in Residential Areas," Journal AWWA Volume 60, Number 5, May 1968.

(29) Keller, C.W., "Pricing of Water," Journal AWWA, January, 1977.

(30) McGarry, R.S., "Risk Management in Water Supply Planning," from The Proceedings for the Water Conservation Conference, Rindge, New Hampshire, July, 1979.

(31) McGarry, R.S., "Water and Sewer Conservation - Oriented Rate Structure," Washington Surburban Sanitary Commission.

(32) McGarry, R.S. and J.M. Brushnighan, "Increasing Water Sewer Rate Schedules: A Tool for Conservation," Journal AWWA, September, 1979.

(33) Meral, G.H., "Local Drought-Induced Conservation in California Experiences," from The Proceedings for the Water Conservation Conference, Rindge, New Hampshire, July, 1978.

(34) North, R.M., "A Review of the Theory of Marginal cost Pricing and its Application to Domestic Water Firms,"

(35) Patterson, W.L., "Application of Water Rates," Journal AWWA, October, 1973.

(36) Pope, R.M, et al., "Effects of Price Change Upon the Domestic Use of Water Over Time," A report to the Office of Water Research and Technology, U.S. Department of the Interior, March, 1975.

(37) Porges, R., "Factors Influencing Per Capita Water Consumption," Water and Sewage Works, May, 1957.

(38) Sheer, D.P., "Analyzing the Risk of Drought: The Occoquan Experience," American Water Works Association Journal, p. 246, May 1980.

(39) Sonnen, M.B. and D.E. Evenson, "Demand Projections Considering Conservation," Water Resources Bulletin, Volume 15, Number 2, April, 1979.

(40) Stewart, R.H. "The Baltimore Region's Water Supply Plan," Journal AWWA, Volume 63, Number 7, September, 1971.

(41) Stewart, R.H. and I. Metzger, "Industrial Water Forecasts," Journal AWWA, March, 1971.

(42) Taylor, E.F. "Crisis Municipal Water Supplies," Journal AWWA, May, 1971.

(43) Turnovsky, S.J., "The Demand for Water: Some Empirical Evidence on Consumers' Response to a Commodity Uncertain in Supply," Water Resources Research, April, 1969, pp. 350-361.

ANNEX G-III

EXAMINATION OF WATER QUALITY AND POTABILITY
FOR THE
METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY

Prepared for the
Department of the Army
U.S. Army Engineer District, Baltimore
Corps of Engineers

by

Jon P. Longtin

Technical Support Division
Office of Drinking Water
Office of Water
U.S. Environmental Protection Agency
Cincinnati, Ohio

September 10, 1982
Revised February 25, 1983

EXAMINATION OF WATER QUALITY AND POTABILITY

FOR THE

METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Cont'd.)

LIST OF FIGURES

INTRODUCTION

The Metropolitan Washington Area (MWA) includes the counties of Loudoun, Prince William, Fairfax, and Arlington in Virginia; the counties of Montgomery, Prince Georges, and Charles in Maryland; and the District of Columbia. The need for publicly supplied water is large and is expected to increase in future years.

The Water Resources Development Act of 1974 (Public Law 93-251) directed the Secretary of the Army, acting through the Chief of Engineers, to: (1) make a detailed study of existing and future water supply needs in the MWA, identifying feasible water supply alternatives and their impacts; and (2) make recommendations to the U.S. Congress on a course of action for meeting both the short-range and long-range water supply needs of the MWA. A Progress Report consisting of a Main Report and nine technical appendices was published in August 1979 documenting the findings of the initial study efforts.

The primary objective of the present effort is to compare the potability of MWA water supply sources under existing water quality conditions. This effort has considered the feasibility of using the various water supply sources in light of available treatment processes and the Environmental Protection Agency's most recent drinking water standards promulgated under the Safe Drinking Water Act (Public Law 93-523). Additionally, the effort includes a very general discussion of potential potability problems and issues with respect to potential future changes as they might apply to the MWA water supply sources.

The level of detail of the analysis was limited to the extent necessary to prepare a relative ranking of existing and potential sources with respect to their desirability as a water supply source, under today's conditions, and to perform a general evaluation as to each source's overall potability.

Studies of this kind involving multiple drainage basins, numerous treatment facilities, different municipal authorities, and a variety of interconnections are complex. To fully define water quality and potability issues requires a level of effort greater than that available for this project. Thus, what is attempted here is an overview which can surface and highlight potential problems of water quality and potability and provide a general assessment of existing and proposed sources and facilities. Even though it is clear that this approach potentially imbeds unknown bias within the results, the level of effort dictated that existing data be used. Thus, no sampling or analysis to obtain new data was done, and existing data were accepted and used on an "as reported" basis. Modeling or projections of trends, although important, was not possible. Another limitation is related to uncertainty in the quality assurance of the information that was obtained. There is no easy way, if any way exists at all, to determine to what degree of confidence the various numbers, originating in different places at different times with different analysts, can be compared.

While it is unsatisfying to restrict comparisons to a somewhat subjective system of ranking, as is done in this report, it is necessary, at this level of effort, if the reality of the information is not to be distorted. Although smaller differences may be masked, significant differences and/or problems, if present, should be revealed.

The basic agreed upon approach was to gather available information and produce a relative ranking of raw and finished waters and facilities with respect to overall water quality. The water qualities were further compared for existing standards. The results of the comparisons and ranking were tabulated and discussed. As a basis for facility comparisons, site visits by a staff member were made. The discussion of the facilities is contained in the following section entitled Plant Descriptions.

PLANT DESCRIPTIONS

Several major water treatment facilities serve the MWA providing treatment of the various source waters. These plants, which range in size from 8 mgd to 200+ mgd basically all provide conventional treatment consisting of coagulation, sedimentation, filtration, and disinfection before the product water is distributed to the consumer. The following section describes the plants owned and operated by WAD, WSSC, FCWA, and the City of Rockville. With one exception (WAD - McMillan), all of these plants were visited by a Technical Support Division (TSD) staff member in June 1982. A narrative description of each plant is presented along with a plant schematic and a design criteria (or current capacities) summary in tabular form.

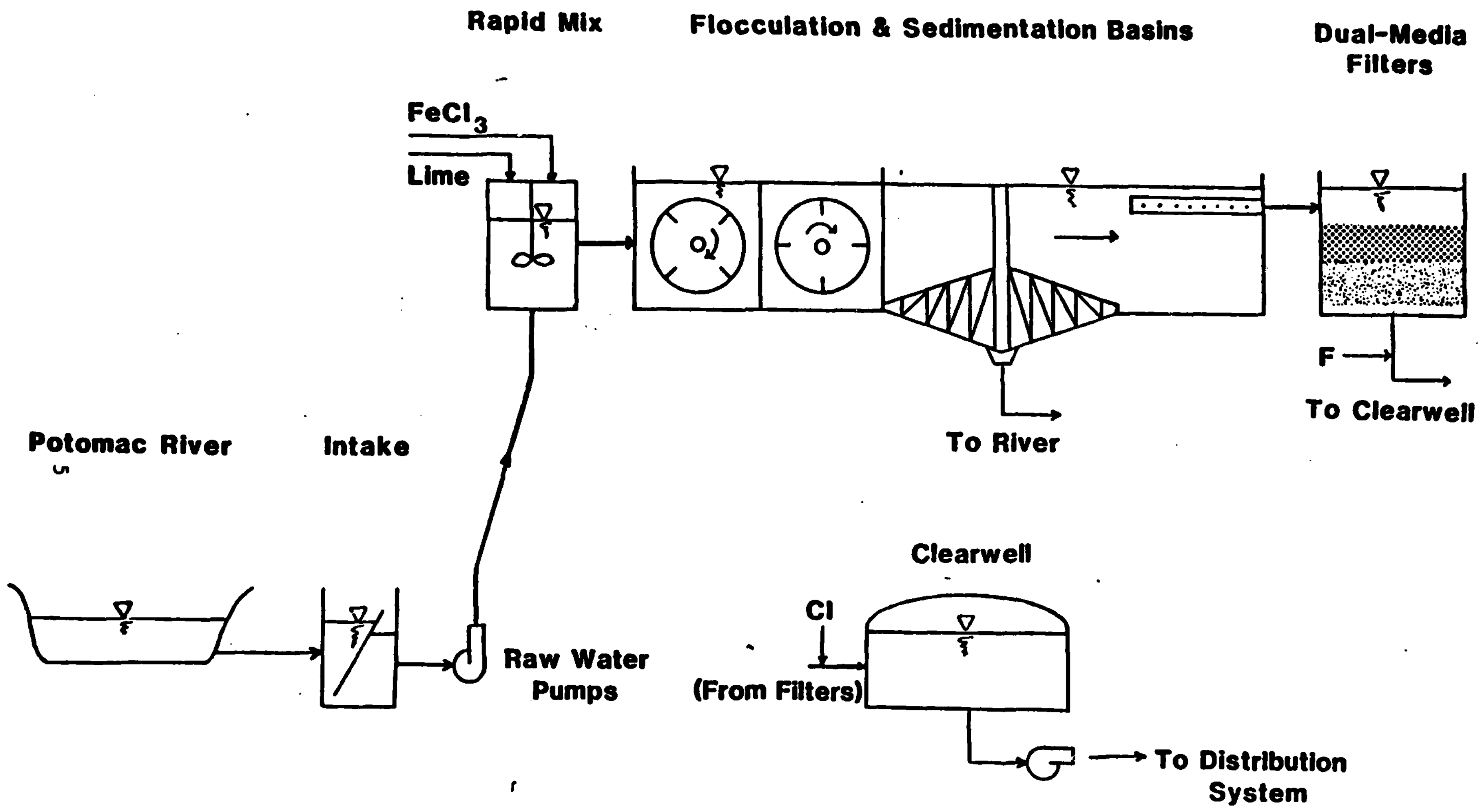
WSSC - POTOMAC PLANT (WATTS BRANCH)

The WSSC Potomac plant is a 200 MGD conventional water treatment plant located on the Potomac River about two miles upstream from Great Falls. The first 60 MGD (peak) stage of this plant went on-line in 1961, with subsequent stages placed into operation in 1971 to bring it up to its current capacity. At present (June 1982) the plant is treating an average daily flow of approximately 114 MGD, with a peak capacity of 240 MGD. In the near future, the capacity will be expanded to 300 MGD (nominal) mainly by reducing head losses through the plant.

The raw water from the Potomac River passes through a bar screen as it enters the intake structure located on a man-made channel of the Potomac. It then flows by gravity under the C&O canal to the raw water pumping station where it passes through a traveling water screen before it is pumped to the rapid mix chambers. At the rapid mixer, ferric chloride and lime are added to promote coagulation. From the mixing chamber the chemically dosed raw water flows through the flocculation basin where paddle flocculators gently mix the water for about 15 minutes to promote floc growth. Following flocculation the floc is allowed to settle out in the scrapper-equipped, sedimentation basins. These settled solids are then returned to the Potomac River untreated via the plant drain. There is a provision in the new modification that would permit backwash water and settled solids to be returned to the raw water pumping station. From this point the backwash water could be recirculated to the plant and the settled solids could be pumped to an appropriate treatment unit (not yet constructed). The settled water is applied to the filters which have recently (Fall 1981) had dual-media installed. The media consists of 14 inches of anthracite coal over 10" of sand on top of graded gravel. Backwashing of the filters is accomplished by the use of large (23,000 gpm) washwater pumps every 60-70 hours of filter use. The backwashing cycle generally takes about 8 minutes and includes a surface wash phase.

The filtered water is collected in plenums located under the filters from which it flows by gravity to a covered finished water reservoir where it is chlorinated and subjected to additional detention time. Large pumps in the finished water pumping station pump the finished water to the Wheaton Reservoir and the Shady Grove Reservoir.

The current phase of modification to the Potomac plant should be completed in December of 1982 and brings the capacity up to 270 MGD. A schematic drawing of the plant is included as Figure 1 and the design criteria are shown in Table 1.



WSSC – Potomac Water Filtration Plant [5]

Figure 1

TABLE 1

POTOMAC WTP

Design Criteria
or
(Current Capacities)

Intake

Capacity	40 MGD
Bar Screens	Yes

Raw Water Pumping Station*

Traveling Screens	Yes
# Pumps	6-50 MGD (with provision for two more)
Type	two-stage centrifugal

Water Treatment Plant

Raw Water Characteristics

Parameter

	Avg.	Min.	Max.
pH	7.8	6.5	9.1
Alkalinity	66	12	130
Total Hardne	110	22	180
Temp. °C	14.3	1	31

Rapid Mix

Number of Tanks	2
Detention Time, min.	<1 min.

Flocculation Basins

Number of Basins	8 (4 on each side)
Detention Time	approx. 14 min @ peak flow
Type	paddle

* New pumping station to go into service in 1983 - old pumping station has total capacity of 260 MGD (4-50 MGD and 2-30 MGD pumps).

TABLE 1

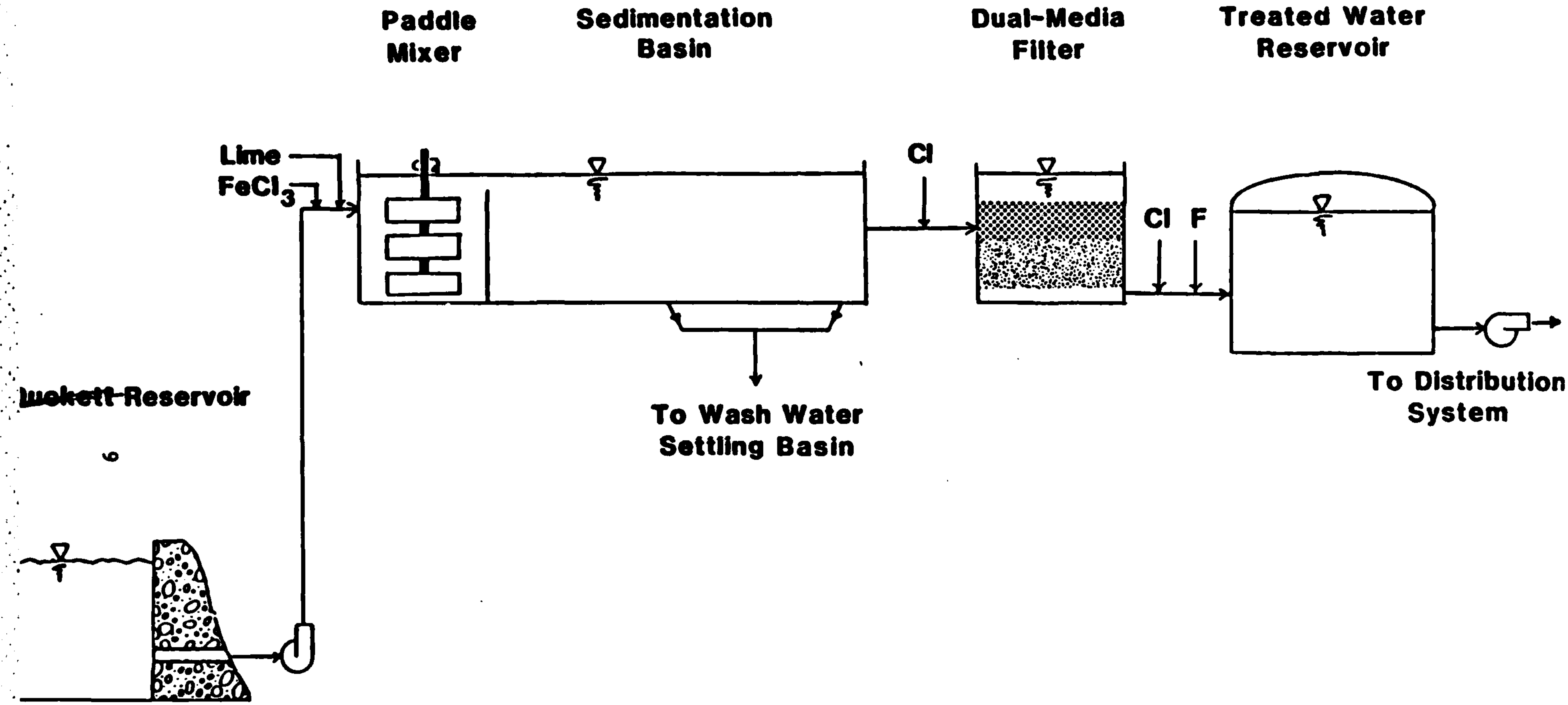
POTOMAC WTP

Design Criteria (Cont'd.)

Sedimentation Basins	
Number of Basins	8 (4 on each side)
Detention Time	72 min.
Sludge Collectors	Yes
Filters	
Number of Filters	32 (16 per side)
Area/Filter	1,275 ft^2
Max. Filtration Rate	5.5 $gal/ft^2/day$
Max. Filtration Cap.	10 MGD/filter
Filter Media	Dual-media
Backwash	
Max. Rate	23,000
Design Time	8 min.
Surface Wash	Yes
Finished Water Storage	
Underfilter	Yes, limited
Clearwell	22 mil. gal.
Finished Water Pumping Sta.	
Pumping Capacity	280 MGD
Solids Dewatering	Settled solids and backwash water returned to river.
Disinfection	Chlorine added at head of clearwell.
Chemicals and Storage	Bulk storage of $FeCl_3$ and lime.

WSSC - PATUXENT WATER FILTRATION PLANT

The older of the two WSSC plants is the 65 MGD Patuxent water filtration plant located about two miles from the Patuxent River near Laurel, Maryland. Raw water from the Duckett Reservoir is pumped to the plant theough three parallel lines to the plant. Treatment at the all-welded steel plant consists of coagulation, sedimentation, and filtration (Figure 2). The four individual, circular-shaped units are constructed in the form of three concentric rings. The inner ring houses the pipe gallery, the middle ring contains the mixing and flocculation zone and rapid sand filters, while the outer ring functions as the sedimentation basin. Figure 2 shows a schematic of one of these units. Raw water to which ferric chloride and lime have been added enters the flocculation zone in the middle annular ring (the mixers are not now in use) to promote the building of floc. The water then flows to the larger annular ring where sedimentation takes place followed by rapid sand filtration through approximately 24 inches of sand media. The units are currently being upgraded (unit #1) through the addition of baffle walls and effluent launderer troughs in the sedimentation zone and surface wash piping (and relocated washwater troughs) in the filters. Mixed media consisting of 19" of anthracite filter media, 9" of silica sand over graded sand and gravel are also being installed. A new chemical building will house lime, ferric chloride, and chlorine storage as well as fluoride. New instrumentation is also being provided in the renovation. The upgrading is not expected to increase the plant capacity much over the current 65 MGD. The design criteria for the plant are listed in Table 2.



WSSC – Patuxent Water Filtration Plant

Figure 2

TABLE 2

PATUXENT WTP

Design Criteria
or
(Current Capacities)

Intake

Capacity	160+ MGD
Bar Screens	Yes, 1" spacing between bars, followed by fine screens.

Raw Water Pumping Station

Traveling Screens	@ intake
# Pumps	9 (4 @ 4 MGD, 1 @ 11 MGD, 1 @ 14 MGD, 3 @ 16 MGD)
Type	centrifugal, horizontal shaft, double suction

Water Treatment Plant

Raw Water Characteristics

Parameter

	Avg.	Min.	Max.
pH	7.1	6.2	7.6
Alkalinity	21	12	28
Total Hardne	31	21	39
Temp. °C	12.6	2	26

Mixing	Chemical mixing is accomplished by in-line static mixers.
Flocculation Basins	Not being used at present - renovated tanks will utilize flocculation.
Number of Basins	4
Detention Time	30-45 min.

TABLE 2

PATUXENT WTP

Design Criteria (Cont'd.)

Sedimentation Basins	
Number of Basins	8 - half annular rings ~ 161 ft. O.D.
Detention Time	2.6 hrs @ 65 MGD
Sludge Collectors	No
Filters	
Number of Filters	24 (6 per unit)
Area/Filter*	#1 unit - 6 @ 604 ft^2, units 2, 3, and 4 - 4 @ 604^2, 2 @ 806 ft^2
Max. Filtration Rate	2 gpm/ft^2 @ 45 MGD; 2.88 gpm/ft^2 @ 65 MGD
Max. Filtration Cap.	65 MGD
Filter Media	Currently 24" - converting to mixed media (garnet, sand, coal)
Backwash	140,000 backwash storage tank
Max. Rate	13,500 gpm
Design Time	3-6 min.
Surface Wash	No, to be added in renovation
Finished Water Storage	
Clearwell	Yes, 7 tanks - total capacity of 18.4 mil. gal.
Finished Water Pumping Sta.	
Pumping Capacity	3 pumps rated @ 22 MGD 2 pumps rated @ 4 MGD (pumps 7 MGD to high zone, 45 MGD to low zone)
Solids Dewatering	Settled solids and backwash water pumped to washwater settling basin.
Disinfection	Chlorine applied ahead of the filters.
Chemicals and Storage	Currently use headhouse - new chemical storage facility to come on-line soon.

* Total Filter Area = 15,708 ft2

DALECARLIA FILTRATION PLANT

The Dalecarlia filtration plant, operated by the Washington Aqueduct Division, is a rapid sand filter plant with a nominal rated capacity of 164 MGD. The original plant was completed in 1927 with a rated capacity of 80 MGD. Additional filters were added in 1951 and again in 1964 bringing the total capacity up to its present level.

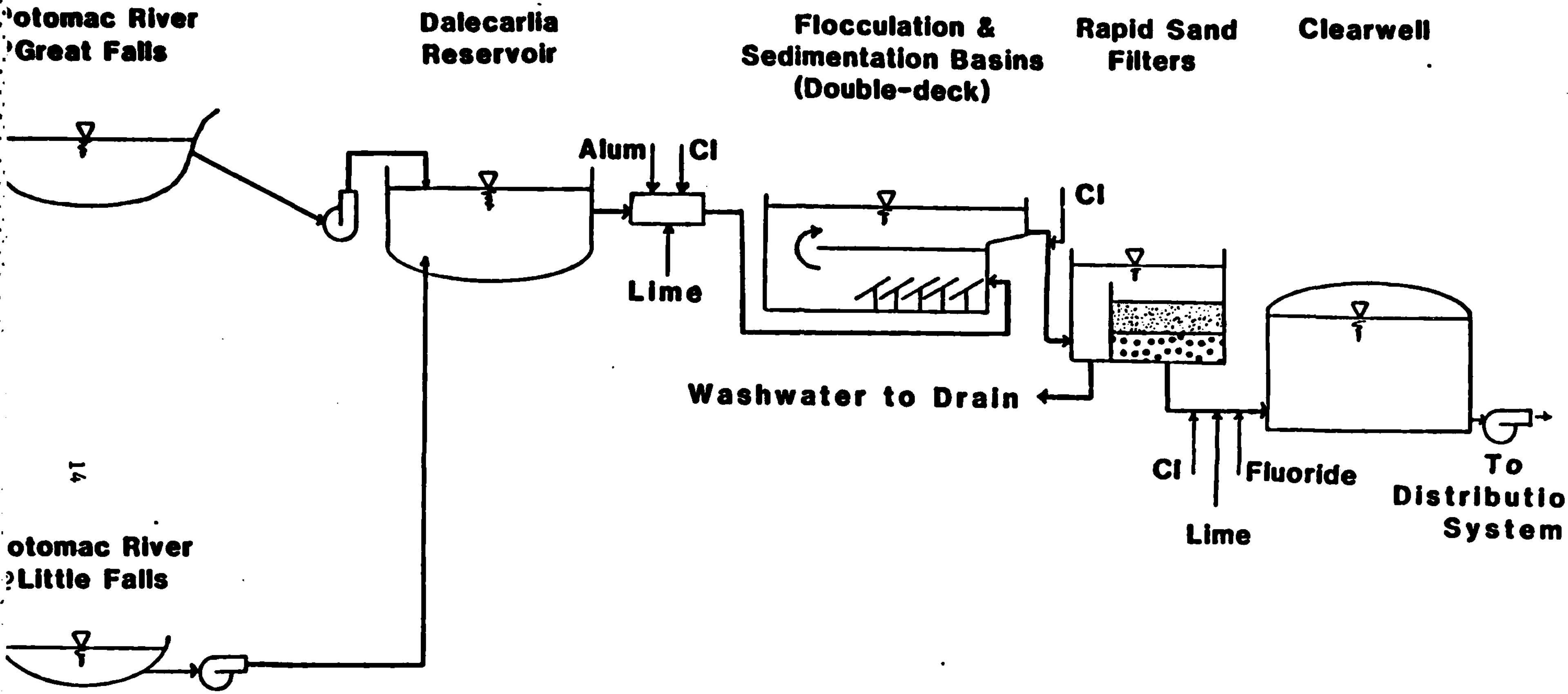
The raw water source for the Dalecarlia filtration plant is the Dalecarlia Reservoir which is supplied from an intake located on the Potomac River at Great Falls, supplemented by water from a pumping station located at Little Falls on the Potomac River (which is always required during the summer months). After screening, alum is added as the raw water passes through the Parshall metering flumes. Following chemical addition, the flow enters the four flocculation/sedimentation basins. Two of these basins (#1 & 2) are part of the original plant and utilize mechanical flocculation to promote the building of a settleable floc before the water enters the sedimentation zone. These two-pass, rectangular concrete sedimentation basins are each approximately 335 feet long and 150 feet wide and have a volume of 4 million gallons each.

In 1949, a much larger (14 million gallon), two-story flocculation-sedimentation basin was added followed by a second of similar design in 1966. Figure 3 shows a profile view of the plant and illustrates the basic design of these basins. Basically, the principle of operation is quite simple. Water enters the flocculation portion of the basin (lower zone) through distributing ports and is gently agitated as it encounters six rows of flocculator paddles. The water then continues to flow through the lower sedimentation zone until it reaches the far end of the basin. At this point, it flows vertically upward (to the upper level) and back towards the head end of the basin. The total retention time in the sedimentation zone is approximately 5.4 hours. Sludge from these basins is returned to the Potomac River. WAD is awaiting EPA's decision on whether this practice may continue or if a sludge recovery facility (already designed) must be constructed.

The settled water then flows by gravity from the sedimentation basins to the rapid sand filters. The twenty-six original filters each have a rated capacity of four MGD while the newer filters (10) are rated at six MGD. The design filtration rate for all of the filters is 2 gallons per minute per square foot of surface area. Crushed anthracite coal or sand is used as the filter media. Eleven and a half additional filter shells have been constructed but not equipped. Elevated wash water storage reservoirs are provided for backwashing the surface-wash equipped filters. Since July 1982, the backwash water has been recirculated to the Dalecarlia Reservoir.

Chlorine is added to the filtered water as a post-disinfectant to obtain the desired residual in the finished water. Post lime is added to adjust the pH and to control corrosion in the distribution system. Fluoride is added to control dental caries, and sulfur dioxide may be added as necessary to remove excess chlorine.

The filtered and treated water is collected and stored on site in two covered clear water basins, one of 10.5 million gallon capacity, and one of 30 million gallon capacity for a total effective storage capacity of 40.5 million gallons. Low and high service pumps at the 477 MGD Dalecarlia pumping station pump the treated water to Washington, DC; Falls Church, VA; and Arlington, VA.



WAD - Dalecarlia Filtration Plant

Figure 3

McMILLAN FILTER PLANT

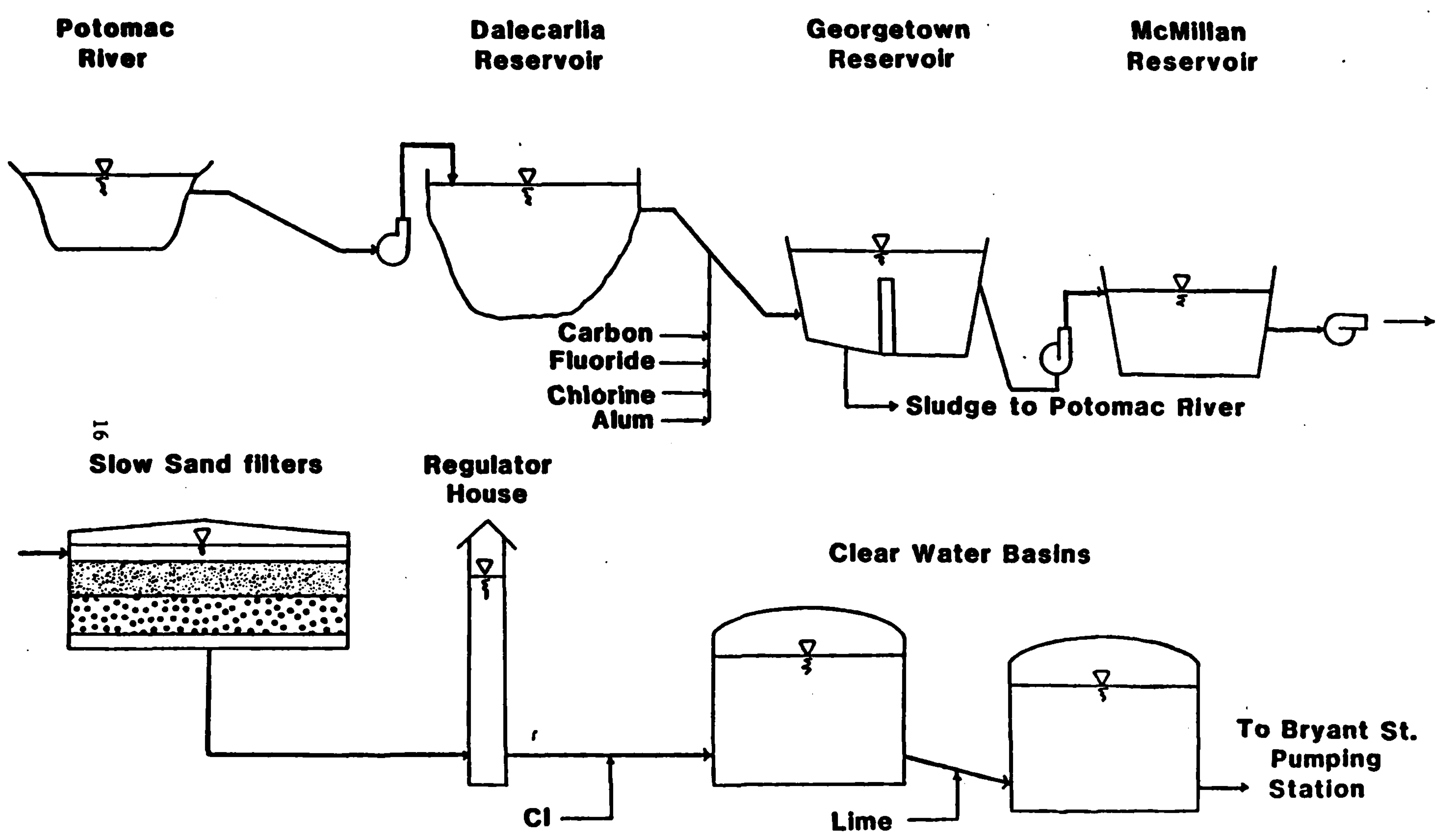
The McMillan filter plant, operated by the Washington Aqueduct Division, is one of the few large slow sand filter plants left in America. Originally built in 1905 to treat 75 MGD, the plant is now rated at 125 MGD mainly because of plant modifications and improved operations.

As with the Dalecarlia filtration plant, the Dalecarlia Reservoir is the source of raw water for the McMillan plant (see Figure 4). The raw water is pretreated with aluminum sulfate and chlorine (also fluoride) at the Dalecarlia plant and then flows by gravity through a 2 mile long conduit (where mixing occurs) to the Georgetown Reservoir which provides between 1-1/4 to 2 days detention time for sedimentation to occur. From the Georgetown Reservoir, the clarified water flows by gravity an additional 5 miles through the Washington City Tunnel to the East Shaft Booster Station where it is pumped up to the McMillan Reservoir. Here the water receives an additional 1 to 1-1/2 days detention time before the water is applied to the filters.

There are 29 slow sand filter beds each having an area of one (1) acre. The filters are of groined arch reinforced concrete construction with a sand depth of 20 inches on top of 12 inches of graded crushed stone. Filtered water is collected by an underdrain system which ties into metered effluent pipes which convey the water to the regulator houses. A large collector main then intercepts the filtered water from the regulator houses and discharges it to the north chamber of two clearwell basins in series with a total capacity of 45 million gallons. After filtering approximately one billion gals, each filter is washed by a tracked, mechanical unit which scrapes and washes the sand. Between washings the sand is raked with a tractor-drawn harrow.

The McMillan Slow Sand Plant is now being replaced by a new Rapid Sand Filter Plant and chemical building. The new facilities are scheduled to go on line in 1985.

Following filtration, the water is chlorinated and the pH is adjusted with hydrated lime. High and low service pumps draw suction from the clearwell basins and pump the finished water to various areas of the Washington, DC area. The design criteria for both the McMillan and Dalecarlia plants is shown in Table 3.



WAD – McMillan Filtration Plant

Figure 4

TABLE 3

WASHINGTON AQUADUCT DIVISION

DALECARLIA WTP & McMILLAN WTP

Design Criteria
or
(Current Capacities)

Intake	**Great Falls**			**Little Falls**		
Capacity	200 MGD			450 MGD		
Bar Screens	Yes			Yes		
Raw Water Pumping Station						
Traveling Screens	Yes			Yes		
# Pumps	gravity			4		
Type	-			centrifugal		
Water Treatment Plant	**Dalecarlia WTP**			**McMillan WTP**		
Raw Water Characteristics						
Parameter	Avg.	Min.	Max.	Avg.	Min.	Max.
pH	7.9	7.0	8.6			
Alkalinity	68	38	123	ditto	ditto	ditto
Total Hardness	114	70	194			
N.C. Hardness	35	19	56			
Temp. °C	16.6	3	31			
Rapid Mix						
Number of Tanks	4 (parshall flumes)			Chemicals added @ Dalecarlia WTP - mixing occurs in 2 mi. long conduit		
Detention Time, min.						
Flocculation Basins	Old (#1 & 2)		New (#3 & 4)			
Number of Basins	2		2 double-deck			
Detention Time	See below					
Type	paddle		six paddle flocculators	None		
Sedimentation Basin						
Number of Basins	2 4 mil. gal. ea.		2 14 mil. gal. ea.	3 basins in Georgetown Reservoir		
Detention Time	4-1/2 to 5 hrs.*		4-1/2 to 5 hrs.*	1-1/4 to 3 days		
Sludge Collectors	No		No	#1 drained 2 times/yr. #2 drained 1 time/yr.		

* Includes flocculation detention time (approx. 45 min.)

TABLE 3

DALECARLIA WTP & MCMILLAN WTP

Design Criteria (Cont'd.)

Filters	Dalecarlia Filter Plant: Old	Dalecarlia Filter Plant: New	McMillan Filter Plant
Number of Filters	16	10	29 slow-sand filters
Area/Filter	1,450 ft^2/filter	2,085 ft^2/filter	1 acre
Nominal Filtration Rate	2 gpm/ft^2	2 gpm/ft^2	0.1 gpm/ft^2 (approx.)
Max. Filtration Cap.	6 MGD/filter	9 MGD/filter	5 MGD/filter
Filter Media	Anthrafilt & Sand	Anthrafilt	20-24" sand
Backwash	Elevated wash water storage		
Max. Rate	30 MGD		None
Max. Rise Rate			
Design Time	Varies - approx. 25 ll/min		
Surface Wash	Yes		
Finished Water Storage			
Underfilter			
Clearwell	2 44 mil. gal. total		2 45 mil. gal. total
Solids Dewatering	Solids to river		
Disinfection	Chlorine, Pre & Post Filtration		Chlorine, Pre & Post Filtration
Chemicals and Storage	Bulk storage of alum, lime, fluoride		Ditto - some chemicals added at Dalecarlia plant

FAIRFAX COUNTY WATER AUTHORITY (FCWA) - OCCOQUAN-LORTON TREATMENT FACILITIES

The FCWA Occoquan-Lorton Treatment Facilities include three interconnected treatment plants: the Occoquan Plant, the Old Lorton Plant, and the New Lorton Plant.

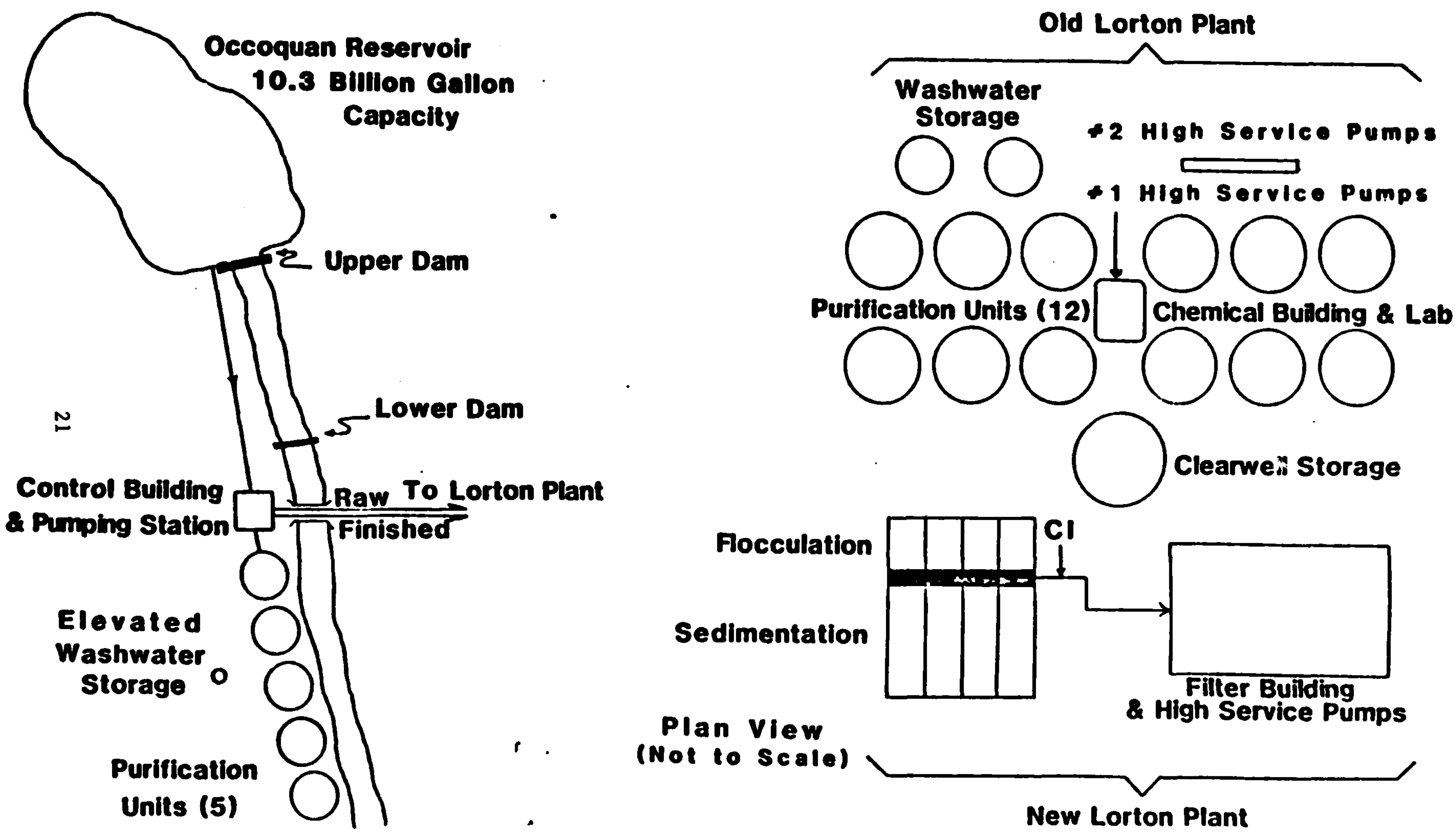
The raw water source of all of these plants is the Occoquan River which is impounded by two dams. A 72 inch raw water transmission line conveys raw water by gravity from the upper dam to two raw water pump stations located on the south (Prince William County) side of the river. A portion of the flow by-passes the pump station and is treated at the Occoquan Treatment Plant while the remainder is pumped across the river for treatment at the Old and New Lorton Treatment Plants (see Figures 5 and 6).

The 40 MGD Occoquan Treatment Plant consists of five steel, circular, upflow units in parallel. Liquid alum, lime, and a coagulant aid are added to the raw water ahead of a flash mixer. After mixing, the raw water enters the tube settler equipped Aldrich units through a rotating distributor arm at the bottom of the tank. The settled water then passes over a steel wall into the annular filter zone, which contains approximately 24 inches of anthracite over 6 inches of sand. Chlorine is added to the settled water prior to filtration. A clearwell is located beneath the treatment units where chlorine, lime, and hydrofluosilicic acid are added to the filtered water. The finished water is then pumped across the Occoquan to the old Lorton plant where high service pumps are used to pump the water out into the distribution system.

The Old Lorton Plant has a total treatment capacity of 39.6 MGD and consists of twelve circular, steel treatment units (similar to those at the Occoquan Plant) with concentric compartments for mixing, sedimentation, and filtration. Lime and alum are added just ahead of a pair of in-line mechanical flash mixers to promote floc growth and coagulation. The raw water then enters the center mixing chamber of the treatment units and flows out into the sedimentation zone. The settled water then flows over a steel curtain wall into the peripheral filter zone which contains 2.5 feet of anthracite on top of 1 foot of sand. Chlorine is added to the settled water prior to filtration. After filtration and prior to storage in the clearwell, chlorine, post-lime, sodium bisulfite (as needed), and hydrofluosilicic acid may be added. The finished water is then pumped from the storage facilities to the distribution system serving Fairfax County.

The New Lorton Plant is a 32 MGD conventional water treatment plant consisting of a single rapid mix chamber, four rectangular flocculation basins, four two-story settling basins, and four two-celled dual-media sand filters. Lime and alum are added to the raw water before and after the rapid mix chamber, respectively. The chemically dosed water then enters the tapered flocculation basins where it is gently agitated before it flows into the settling basins. Chlorine is added to the settled water prior to filtration. The filter media consists of 12 inches of anthracite, 12 inches of sand, 5 inches of torpedo sand, and 10 inches of gravel. Following the addition of chlorine, post-lime, and hydrofluosilicic acid, the filtered water is stored in the interconnected clearwells that serve the Old Lorton Plant.

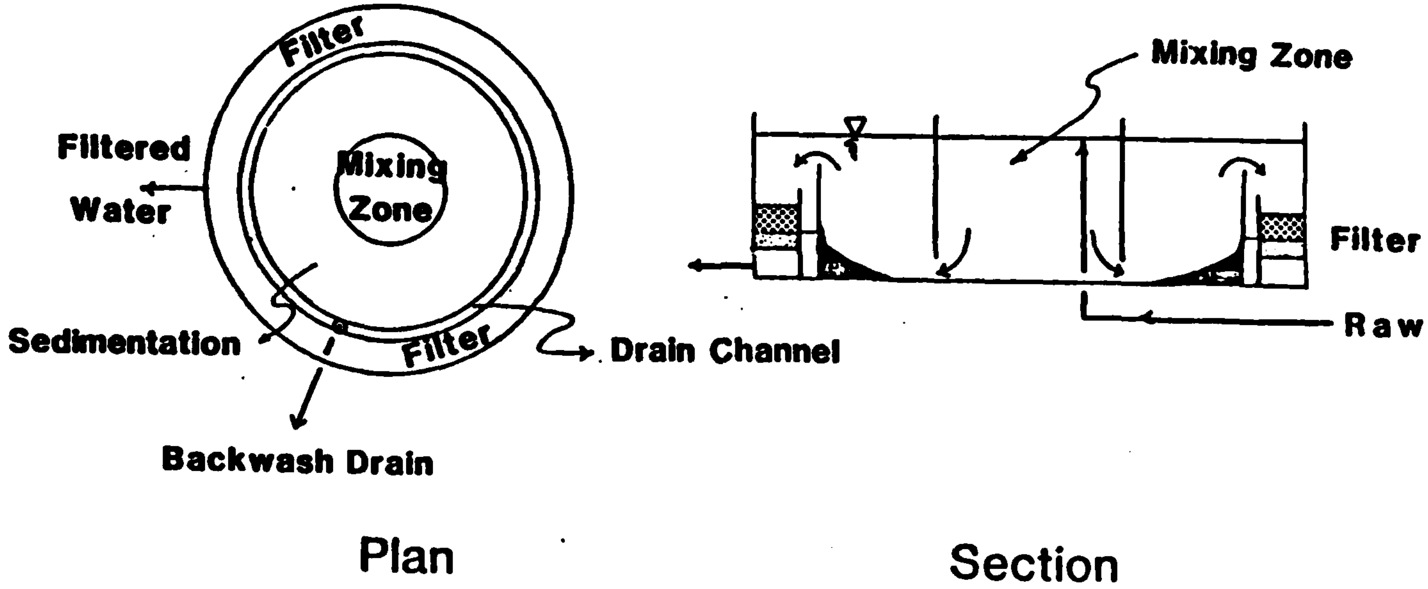
The Fairfax County Water Authority also owns and operates 23 wells, 12 of which are connected directly to the main distribution system. The design criteria for the FCWA facilities are shown in Table 4.



FCWA – Occoquan & Lorton WTP

Figure 5

Typical Purification Unit @ Lorton Plant



FCWA – Occoquan & Lorton WTP

Figure 6

TABLE 4

OCCOQUAN - LORTON TREATMENT FACILITIES

Design Criteria
or
(Current Capacities)

	Occoquan WTP 40 MGD (Peak Cap.)	Lorton Facilities OLD 39.6 MGD (Peak)	Lorton Facilities NEW 32 MGD (Peak)
Intake			
Capacity	72" gravity line		
Bar Screens	Yes		
Raw Water Pumping Station			
@ Occoquan Plant			
Traveling Screens	Yes	6 (2 @ 6 MGD 2 @ 12 MGD)	3 @ 15 MGD (500 HP)
# Pumps	(gravity flow to Occoquan WTP)		
Type		Centrifugal	Centrifugal
Water Treatment Plant			
Raw Water Characteristics		ditto	ditto

Parameter	Avg.	Min.	Max.
SS	-	-	-
pH	7.0	5.9	8.6
Alkalinity	35	10	113
Total Hardness	50	22	176
N.C. Hardness	-	-	-
Temp. °C	15	1	29

	Occoquan WTP	Lorton OLD	Lorton NEW
Rapid Mix			
Number of Tanks	-	2~30 in. in-line mixers	1 (1990 ft^3)
Detention Time, min.			.7 min. (42 sec.)
Max. Vel. Gradient			
Max. GT			40 HP flash mixer
Flocculation Basins	*		
Number of Basins		12 mixing compartments	4
Detention Time	1.5 hrs. @ 40 MGD	6,250 ft^3 ea. ~ approx. 20 min.	23 min. @ 32 MGD
Type	Radial distributor		Horiz. paddle
Number of Stages	-		
Max. Vel. Gradient	-		Tapered flocculation

* Flocculation provided by rotating, radial distributor arm.

TABLE 4

OCCOQUAN - LORTON TREATMENT FACILITIES

Design Criteria (Cont'd.)

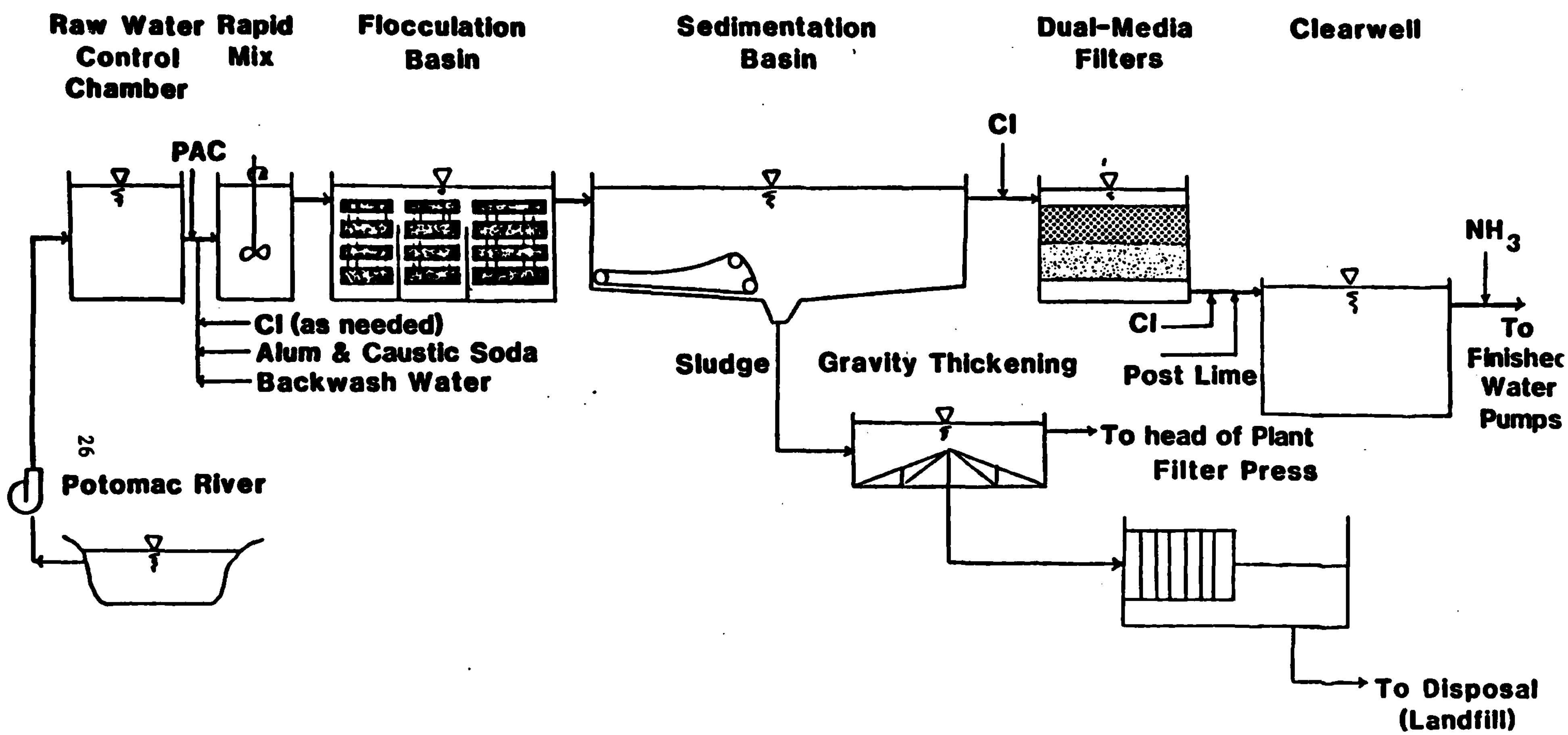
	Occoquan WTP	Lorton Facilities	
	40 MGD (Peak Cap.)	OLD 39.6 MGD (Peak)	NEW 32 MGD (Peak)
Sedimentation Basins			
Number of Basins	5~86 ft dia.	12~56,500 ft^3 ea.	4 (357,000 ft^3 total)
Detention Time	1.5 hrs. @ 40 MGD (includes flocculation)	3.1 hrs.	2 hrs. @ 32 MGD
Surface Loading Rate		-	
Sludge Collectors	no - tube settler equipped	No	No
Filters			
Number of Filters	5	12	4 (two-celled)
Area/Filter	1,400 ft^2	?	1,396 ft^2/filter
Max. Filtration Rate	4 gpm/ft^2	3 gpm/ft^2	4 gpm/ft^2
Max. Filtration Cap.	8 MGD	3.3 MGD	8 MGD
Filter Media	24" Anthracite 6" Sand Over Gravel	30" Anthracite 12" Sand	Mixed Media (12" Anthracite 12" Sand 5" Torpedo 10" Gravel)
Backwash	Elevated Storage	Elevated Storage	
Max. Rate	25,000 gpm (high wash)	-	10,500 gpm
Max. Rise Rate	1,000 gpm (low wash)	-	Pumps from clearwell
Design Time	6 min. H, 3 min. L	-	-
Surface Wash	No	No	No
Finished Water Storage			
Underfilter Clearwell	1.7 mil. gal. (adj. to filters)	Three interconnected clearwells	
Finished Water Pumping Sta.			
Pumping Capacity	5 pumps (2~12 MGD 2~6 MGD 1~4 MGD	Three on-site pumping stations with total pumping capacity of 125 MGD with the largest pump out. (133 MGD with <u>all</u> pumps)	
Solids Dewatering	To Occoquan River	To abandoned quarry	
Disinfection	Cl prior to filter (post Cl @ clearwell if needed)	Cl prior to filters (post Cl @ clearwell if needed)	
Chemicals and Storage	Chlorine, Liquid Alum, Hydrated Lime, Hydrofluosilicia Acid	Chlorine, Pebble Lime, Liquid Alum	

FAIRFAX COUNTY WATER AUTHORITY (FCWA) - POTOMAC RIVER WTP

The 50 MGD (peak flow) Potomac River WTP is the newest of the Fairfax County Water Authority (FCWA) plants. The plant treatment consists of chemical mixing, flocculation, sedimentation, filtration, pH adjustment, and post-disinfection.

The current maximum withdrawal rate from the Potomac River is 24 MGD. The raw water is pumped approximately 5 miles from the 200 MGD intake to the plant where it first passes through the raw water control chamber (see Figure 7) where pre-chlorine, caustic soda, powdered activated carbon (PAC), and flouride may be added. A constant speed turbine mixer is provided at this point for mixing. From this point, the water flows to the four rapid mix chambers equipped with variable speed turbine mixers. Alum is added at this point along with a coagulant aid, if needed. Following the rapid mix basins the flow enters the tapered flocculation basins which are equipped with variable speed, paddle-type, flocculator units. Water from the flocculation basins passes through a baffle wall and enters the sludge collector-equipped sedimentation basins. At the design flow rate of 50 MGD, approximately 3 hrs of detention time are provided in the basins. Following sedimentation, chlorine is added to the settled water as well as a filter aid or PAC, if needed. The settled water is then applied to the high rate filters (8) where the filter rate is controlled by venturi meters and electrically operated butterfly valves. A computer with color graphics capability is used to monitor the filtration process. The filtered water is chlorinated as it enters the clearwells located under the filters. From the filter clearwells the water flows by gravity to the main filter clearwell (5.5 million gal. capacity) where lime is added for pH adjustment. Ammonia is also added at the end of the clearwell to provide for a combined residual in the distribution system. Finished water is pumped from the clearwell to the distribution system by five pumps which operate in series and/or parallel.

Settled sludge from the sedimentation basins is first thickened in gravity thickeners before it is dewatered by filter presses for landfill disposal. Washwater from the filter backwashing cycle drains to the washwater reclamation basin where it is then pumped at a controlled rate back to the head of the plant for treatment. The design criteria for the plant are shown in Table 5.



FCWA – Potomac River WTP

Figure 7

TABLE 5

FAIRFAX COUNTY WATER AUTHORITY

POTOMAC RIVER WTP

Design Criteria
(Based on flow of 50 MGD)

Intake

Capacity	200 MGD
Bar Screens	Yes, 3" clear space

Raw Water Pumping Station

Traveling Screens	Yes, 3/8" clear space
# Pumps	3
Type	1 - 30 MGD const. speed 1 - 30 MGD var. speed 1 - 20 MGD var. speed

Water Treatment Plant

Raw Water Characteristics

Parameter

	Avg.	Min.	Max.
SS	40	1	1125
pH	7.7	6.8	9.2
Alkalinity	60	25	110
Total Hardness	101	52	180
N.C. Hardness	41	27	70
Temp. °C	16	0	31

Rapid Mix

Number of Tanks	4 (with var. speed range)
Detention Time, sec.	20 sec
Max. Vel. Gradient	1000 sec^{-1}
Max. GT	20,000

Flocculation Basins

Number of Basins	4
Detention Time, min.	33 min
Type	12' dia. paddle type
Number of Stages	3
Max. Vel. Gradient	41,600 (Stage 1) 33,200 (Stage 2) 20,800 (Stage 3)

TABLE 5

POTOMAC RIVER WTP

Design Criteria (Cont'd.)

Sedimentation Basins	
Number of Basins	4
Detention Time, hrs	3 hrs
Surface Loading Rate	0.5 gpm/ft^2
Sludge Collectors	Yes, chain flight
Filters	
Number of Filters	8
Area/Filter	1,240 ft^2
Max. Filtration Rate	4 gpm/ft^2
Max. Filtration Cap.	7.1 MGD/filter
Filter Media	Anthracite - 18" Filter Sand - 12" Graded Sand/Gravel - 15"
Backwash	
Max. Rate	20 gpm/ft^2
Max. Rise Rate	32 in/min
Design Time	15 min
Surface Wash	Yes, 1.0 gpm/ft^2
Finished Water Storage	
Underfilter	1.0 mil. gal.
Clearwell	5.5 mil. gal.
Finished Water Pumping Sta.	
Pumping Capacity	2 @ 18,700 gpm @ 122' TDH (800 HP) 3 @ 23,000 gpm @ 185' TDH (1,500 HP) Firm capacity (series mode) 52 MGD @ 310' TD
Solids Dewatering	
Type	Filter Presses
Number of Presses	2
Design Pressure	225 psig
Filter Area/Press	3,700 ft^2
Disinfection	Pre- and post filter chlorination followed by ammonia at end of clearwell.
Chemicals and Storage	Bulk storage of caustic soda, lime, fluoride powdered activated carbon (PAC).

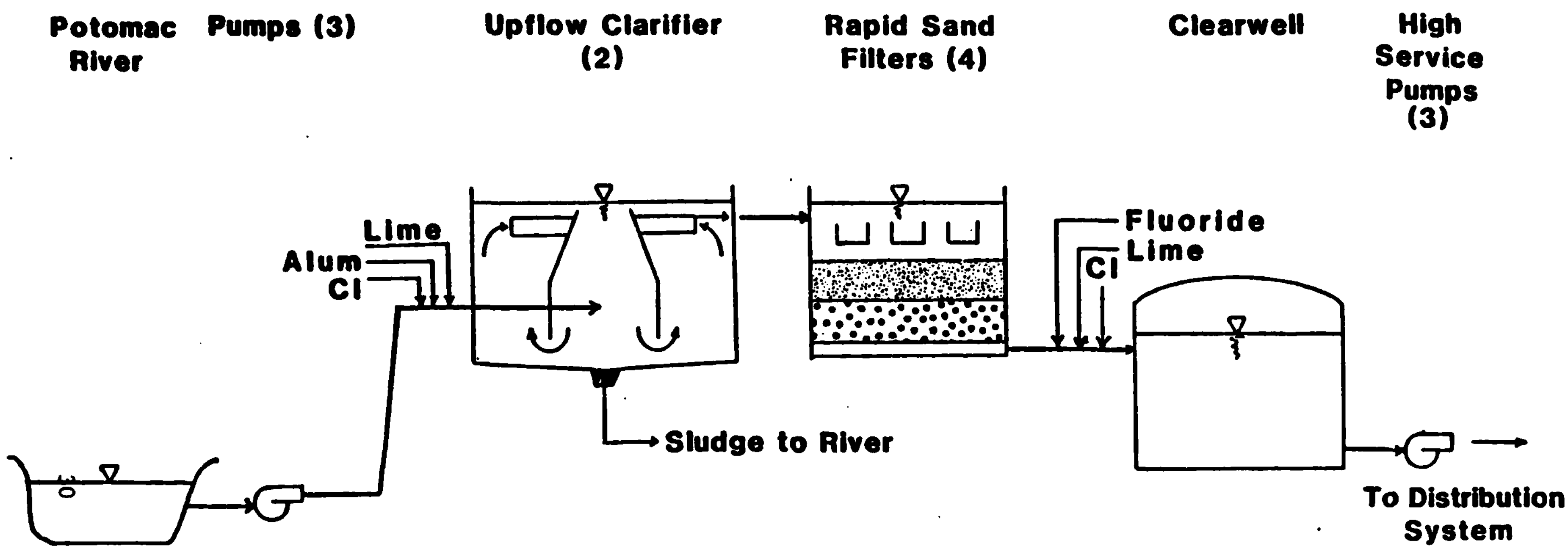
CITY OF ROCKVILLE

The Rockville WTP is an 8 MGD conventional treatment plant (flocculation, sedimentation, and rapid sand gravity filters) originally built in 1958 (with a capacity of 4 MGD) that serves a population of 45,000. In 1968 the plant capacity was increased to its current capacity.

Submersible pumps at the intake on the Potomac River pump the raw water through a 24 in. line to two upflow clarifiers each rated at 4,000,000 gallons a day. Aluminum sulfate (alum) is added in the clarifier centerwell to aid in coagulation along with hydrated lime for pH control. Carbon may also be added to the centerwell as needed for taste and odor control. The settled floc is discharged back to the river. The clarified water flows from the clarifiers to the four uncovered (ice is sometimes a problem in the winter) gravity filters each rated at 2,000,000 gallons per day. The filter media consists of two feet of "Anthrafilt" (graded anthracite coal) on four layers of graded gravel. Filtered water is collected in a 225,000 gallon clearwell located under the pipe gallery. Hydrofluosilicic acid is added to the clearwell for the prevention of dental caries, chlorine for microorganism control, and hydrated lime for corrosion control. Three high service pumps take suction from the clearwell and pump to elevated storage and the distribution system.

Backwashing of the filters is done by means of a 10,500 gpm wash water pump taking suction from the clearwell. Surface wash is also provided.

Growth in this area was quite rapid when the plant was first built, but now it has somewhat leveled off. Since the average treated water flow is only about 5 MGD, and the plant capacity is 8 MGD, no major plant expansions are anticipated. A diagram of the plant is included as Figure 8 and the design criteria are listed in Table 6.



Rockville WTP

Figure 8

TABLE 6

ROCKVILLE WTP

Design Criteria
or
(Current Capacities)

<u>Intake</u>

Capacity	12 MGD (peak)
Bar Screens	Yes

<u>Raw Water Pumping Station*</u>

Traveling Screens	Yes
# Pumps	3
Type	Submersible 4.4 MGD each

<u>Water Treatment Plant</u>

Raw Water Characteristics

<u>Parameter</u>

	Avg.	Min.	Max.
pH	8.1	7.4	10.6
Alkalinity	69	41	176
Total Hardness	82	58	191
Temp. °C	14.1	1	29

Rapid Mix

Number of Tanks	2 - center-well of upflow clarifiers
Flocculation Basins	Yes, integral to upflow clarifier.

Sedimentation Basins

Number of Basins	2 upflow clarifiers 53' sq. x 17' deep 4 MGD each
Detention Time	approx. 2.1 hrs @ 8 MGD
Sludge Collectors	Drawoffs - discharged back to Potomac River

TABLE 6

ROCKVILLE WTP

Design Criteria (Cont'd.)

Filters	
Number of Filters	4
Area/Filter	882 ft^2/filter
Max. Filtration Rate	2 gpm/ft^2
Max. Filtration Cap.	8 MGD
Filter Media	24" anthrafilt over graded gravel
Backwash	
Max. Rate	10,500 gpm
Max. Rise Rate	1.6 ft/min.
Design Time	varies, but approx. 18 min.
Surface Wash	Yes
Finished Water Storage	
Underfilter	225,000 gals.
Finished Water Pumping Sta.	
Pumping Capacity	3 centrifugal pumps (400 HP each) 2,800 gpm each
Solids Dewatering	Pumped back to river
Disinfection	Chlorine ~ pre-chlorine added to raw lime; post-chlorine added to clearwell
Chemicals and Storage	Bulk storage for lime (30 T) and alum (30 T)

WATER QUALITY STANDARDS AND POTABILITY

Since this report will provide a comparative assessment of the relative quality of both raw and finished water for the water supplies in the Metropolitan Washington Area, it is necessary to establish the benchmarks against which comparisons can be made. In addition, the question of quality with respect to potability is examined. There is a fundamental problem in evaluating potability in that there is no generally accepted measure for it. Such a measure depends on many factors involving both health and esthetic considerations. Many of these factors are complex and can act in a synergistic way. Unfortunately, our knowledge of these factors, their interactions, and their effects is not complete. New materials are still being found in water supplies, and the health consequences are still being elaborated. Thus, our perspective of potability changes as our knowledge and experience accumulate. While an absolute definition of potability does not exist, as a minimum, water to be considered potable should at least meet those standards and regulations which reflect current understanding and experience. Thus, the operating approach to making evaluations in this report will be to assume that the existing applicable standards provide the minimum criteria for assessing potability. Existing water supplies will be evaluated against these standards.

DRINKING WATER

The current drinking water regulations for the United States are promulgated by EPA and are identified as the National Interim Primary Drinking Water Regulations (NIPDWR)[1] and the EPA National Secondary Drinking Water Regulations (NSDWR).[2] These two sets of regulations reflect different bases. First, the NIPDWR are based on health risk considerations and are mandatory. Second, the NSDWR represent esthetic aspects of consumer acceptance such as taste, odor, color, turbidity, etc., and are recommended but not mandatory. Both the EPA NIPDWR and NSDWR are presented as part of Table 7.

Some parameters such as ammonia and cyanide are not addressed in the current EPA standards but are dealt with in other well established standards including the European Standards for Drinking Water (WHO)[3] and the Public Health Service Drinking Water Standards.[4] These are shown in Table 7 along with those promulgated by EPA. Inspection of the table shows that in general, corresponding limits for different standard sets, where comparable, are, for practical purposes essentially the same. This supports the procedure that in the absence of a specific EPA limit, a reasonable estimate of a limit can be made for evaluation purposes by using one from another set. The result of this procedure is the basis standard set for evaluation and comparison which is essentially the EPA standards augmented where necessary with appropriate values from other sources.

DRINKING WATER SURFACE SUPPLIES

There exists a set of water quality criteria for surface water supplies which was developed by the National Technical Advisory Committee and published in the Water Quality Criteria Report.[5] These criteria are fairly complete and are used as the basis for making surface water supply evaluations. The criteria are presented in Table 8.

TABLE 7

DRINKING WATER STANDARDS

CONSTITUENT OR CHARACTERISTIC	NIPDWR (EPA) MCL	PUBLIC HEALTH SERVICE (1962)	NSDWR (EPA) MCL	EUROPEAN STANDARDS (WHO) 1970	BASIS STANDARD SET
PHYSICAL:					
Foaming Agents (mg/l)			0.5		
Color (Color Units)		15	15		15
Odor (Threshold Odor #)		3	3		3
Temperature					
Turbidity (TU)	1	5			1
Corrosivity			Noncorrosive		Noncorrosive
MICROBIOLOGICAL:					
Coliform Organisms		1/100 ml		1/100 ml	1/100 ml
Fecal Coliforms				1 PFU/Liter	1 PFU/Liter
Enteric Virus					
INORGANIC CHEMICALS (mg/l):					
Alkality					
Ammonia				0.05	0.05
Arsenic	0.05	0.01		0.05	0.05
Barium	1.0				1.0
Boron					
Cadmium	0.01			0.01	0.01
Chloride		250	250		250
Chromium (VI)	0.05			0.05	0.05
Copper		1.0	1.0		1.0
Cyanide		0.01		0.05	0.01
D.O.				<5.0	
Flouride					
Iron (Filterable)		0.3	0.3		0.3
Lead	0.05			0.1	0.05
Manganese		0.05	0.05		0.05
Mercury	0.002				0.002
Nitrates (as N)	10.0	45(NO_3)/10(N)		50-100(NO_3)/11-22(N)	10.0
pH			6.5-8.5		6.5-8.5
Phosphorous					
Selenium	0.01			0.01	0.01
Silver	0.05				0.05
Sulfate		250	250		250
TDS		500	500		500
Uronyl Ion					
Zinc		5.0	5.0		5.0
Hardness				2 to 10 mEq/1 (100 to 500 mg/1 $CaCO_3$)	
Anionic Detergents				0.2	
Free CO_2				0	
ORGANICS (ug/l)					
Endrin	0.2				0.2
Lindane	4.0				4.0
Methoxychlor	100.0				100.0
Toxophene	5.0				5.0
2,4,D	100.0				100.0
Silvex	10.0				10.0
TTHM	100.0				100.0

TABLE 8

SURFACE WATER CRITERIA FOR PUBLIC WATER SUPPLIES

CONSTITUENT OR CHARACTERISTIC	PERMISSIBLE CRITERIA
PHYSICAL:	
Foaming Agents (mg/1)	-
Color (Color Units)	75
Odor (Threshold Odor #)	-
Temperature	-
Turbidity (TU)	-
Corrosivity	-
MICROBIOLOGICAL:	
Coliform Organism	10,000/100 ml
Fecal Coliforms	2,000/100 ml
Enteric Virus	-
INORGANIC CHEMICALS (mg/1):	
Alkalinity	-
Ammonia	0.5 (as N)
Arsenic	0.05
Barium	1.0
Boron	1.0
Cadmium	0.01
Chloride	250
Chromium (VI)	0.05
Cyanide	-
D.O.	-
Fluoride	-
Hardness	-
Iron (Filterable)	0.3
Lead	0.05
Manganese	0.05
Mercury	-
Nitrates (+ Nitrites)	10 (as N)
pH	6.0-8.5
Phosphoroue	-
Selenium	0.01
Silver	0.05
Sulfate	250
TDS	500
Uranyl Ion	5
Zinc	5
Anionic Detergents	-
Free CO_2	-
Copper	1.0

COMPARISON OF RAW AND FINISHED WATER

In order to assist in making water supply decisions, a comparison of the water quality of both raw and finished water for the various supply systems was attempted. It is difficult to quantify water quality into a single parameter. Thus, a ranking procedure was developed and used to approach this problem. The ranking is relative; that is, it does not rank water quality against an absolute scale but rather only ranks the systems within the scope of this report against one another.

RANKING PROCEDURE

In order to compare and rank the water quality as defined by the data, it is necessary to establish a procedure which allows unlike elements to be compared. This is accomplished by first separating the various parameters into representative groups and then comparing within the groups. The group comparisons are then displayed and summarized. The representative groups selected to be used are:

1. Metals (Fe, Mn, Cu, etc.)
2. Minerals (SO_4, NO_3, TDS, etc.)
3. Aesthetics (Color, Odor, Turbidity)

Comparison within groups is done by arraying the grand average of the parameters with their sources and ranking the sources for each parameter.

The ranking procedure is derived from the following rationale. All the parameters used have an upper bound (maximum contaminate level - MCL), which is the regulatory threshold for action. It is assumed that for these parameters, less is better and the "least" receives the lowest numerical rank while the "most" receives the highest numerical rank. The lower the numerical rank, the better the water quality with respect to the specific parameter being ranked. Thus, ranking is done by assigning a rank of one to the source with lowest value, two to that of the next lowest value and so on. Ties are handled by summing the rank values of the tied position, dividing by the number of tied positions, and assigning the result to the tied positions. This keeps the total ranking points constant for each element. The ranks for each source are then summed to provide a composite score upon which an overall group ranking is based.

The rationale for using the composite approach is very simply that the more frequently a raw or finished water ranks above another, the better that water is in comparison. Thus, each parameter presents an opportunity for some relative success in the ranking process. The composite score (the sum of the rankings of all the parameters for a given water) is just the measure of the total or cumulative relative success a given source had in the ranking. The rankings by group for both raw and finished water are shown in Tables 9 through 14.

Group rankings are summarized in Tables 15 and 16. Data used in this procedure represent grand averages of all available data. The number of datum points for each source may be different because more data is available from some sources than from others. The lack of trends observed in most of the parameters supports the assumption that the effects on ranking of using unequal time spans is minimal.

DISCUSSION OF RESULTS

Two facilities, Rockville and the FCWA Potomac Plant, did not have an adequate data base to easily include in the ranking process. They are treated separately. The results for the other existing facilities (WSSC, WAD, and FCWA-Occoquan) are summarized in Tables 15 and 16. Examination of the summed scores or the individual rankings in the group ranking tables (Tables 9 through 14) indicates that no single source or finished water was consistently best or worst. Thus, the final ranking is sensitive to the selected parameters and could be changed by eliminating one or more parameters. This sensitivity indicates that while the ranking show overall differences in water quality, the differences are not strong enough to support a conclusion that the overall water qualities are significantly different.

A consequence of this is that the impact of these differences on water supply decisions will be of a small order of magnitude. One thing this means is that a complete elaboration of these effects would require a considerably more detailed and precise study at a much greater level of effort. On the other hand, it should also be recognized that the small order of magnitude of the potential effects indicates a lesser need for concern.

At the time of this writing, the FCWA Potomac plant has not yet developed enough of a data base to be meaningful. Additionally, as the plant is in start-up status, it probably will be some time before the results reflect the true picture of water quality. The Rockville data did not include as much information as the other systems and thus could not be properly included in the ranking procedure. However, the available data points to a generally poorer raw and finished water quality.

TABLE 9

RAW WATER METAL COMPARISONS

PARAMETER (mg/L)	WSSC POTOMAC	WSSC PATUXENT	WAD POTOMAC	FCWA OCCOQUAN	ROCKVILLE*
Fe	0.700	0.380	0.721	0.601	0.116
Rank	3	1	4	2	
Mn	0.117	0.122	0.065	0.157	0.20
Rank	2	3	1	4	
Cu	0.121	0.053	0.015	0.031	0.272
Rank	4	3	1	2	
As	0.002	0.002	0.002	0.006	-
Rank	2	2	2	4	
Pb	0.022	0.018	0.002	0.004	-
Rank	4	3	1	2	
Hg	0.0002	0.0004	0.0002	0.0005	-
Rank	1.5	3	1.5	4	
Se	0.0009	0.0009	0.003	0.002	-
Rank	1.5	1.5	4	3	
Ag	0.003	0.002	0.0006	0.0004	-
Rank	4	3	2	1	
Zn	0.061	0.214	0.016	0.002	0.12
Rank	3	4	2	1	
Cd	0.002	0.002	0.0006	0.0006	-
Rank	3.5	3.5	1.5	1.5	
Cr	0.004	0.003	0.004	0.014	0.014
Rank	2.5	1	2.5	4	
SCORE	31	28	22.5	28.5	
OVERALL RANK	4	2	1	3	

* NOTE: Rockville is not included in the ranking because of incomplete data.

TABLE 10

RAW WATER MINERAL COMPARISONS

PARAMETER	WSSC POTOMAC	WSSC PATUXENT	WAD POTOMAC	FCWA OCCOQUAN	FCWA POTOMAC	ROCKVILLE**
Sulfate ($mg/L\ SO_3$)	34.4	7.5	29	16.8	54.5*	
Rank	4	1	3	2		
Chloride	14.7	11.1	14.4	11.9	16.6*	22.0
(mg/L Cl)	4	1	3	2		
Nitrate (mg/L N)	4.9	3.7	1.33	0.56	0.80*	
Rank	4	3	2	1		
Total Dissolved Solids (TDS) (mg/L)	188	60	183	86.5*	112.5*	
Rank	4	1	3	2		
Score (with TDS)	16	6	11	7		
Overall Rank with TDS	4	1	3	2		
Score without TDS	12	5	8	5		
Overall Rank without TDS	4	1.5	3	1.5		

* 1981 data only.

** NOTE: Rockville is not included in the ranking because of incomplete data.

TABLE 11

RAW WATER AESTHETIC COMPARISONS

PARAMETER	WSSC POTOMAC	WSSC PATUXENT	WAD POTOMAC	FCWA OCCOQUAN	ROCKVILLE**
Color (Color Units)	7.35	4.28	34.2	51.5	-
Rank	2	1	3	4	
Odor*** (Odor Number)	3.29	2.30	-	27.1*	4.4
Rank					
Turbidity (JTU)	43.08	9.30	23.7	13.27	54.47
Rank	4	1	3	2	-
Score	6	2	6	6	
Overall Rank	3	1	3	3	

* 1981 Data only.
** NOTE: Rockville is not included in the ranking because of incomplete data.
*** NOTE: Odor not used in ranking because data not available.

TABLE 12

FINISHED WATER METAL COMPARISONS

PARAMETER (mg/l)	WSSC POTOMAC	WSSC PATUXENT	WAD DALECARLIA	WAD McMILLAN	FCWA OCCOQUAN	FCWA OLD LORTON	FCWA NEW LORTON	ROCKVILLE*
Fe	0.072	0.059	0.026	0.039	0.016	0.086	0.054	0.065
Rank	6	5	2	3	1	7	4	
Mn	0.025	0.020	0.007	0.008	0.006	0.007	0.003	0.03
Rank	7	6	3.5	5	2	3.5	1	
Cu	0.016	0.033	0.006	0.042	0.008	0.009	0.008	0.171
Rank	5	6	1	7	2.5	4	2.5	
As	0.001	0.010	0.001	0.007	0.006	0.006	0.006	
Rank	2.5	7	2.5	1	5	5	5	
Pb	0.032	0.011	0.001	0.0014	0.004	0.004	0.006	
Rank	7	6	1	2	3.5	3.5	5	
Hg	0.0001	0.0005	0.0002	0.0001	0.0005	0.0005	0.0003	
Rank	1.5	6	3	1.5	6	6	4	
Se	0.0008	0.0006	0.002	0.002	0.002	0.002	0.003	
Rank	2	1	4.5	4.5	4.5	4.5	7	
Ag	0.004	0.002	0.0004	0.0002	0.0002	0.0002	0.0003	
Rank	7	6	5	2	2	2	4	
Zn	0.049	0.101	0.0097	0.012	0.0003	0.003	0.004	0.21
Rank	6	7	4	5	1	2	3	
Cd	0.004	0.006	0.0004	0.0003	0.0004	0.0004	0.0006	
Rank	6	7	3	1	3	3	5	
Cr	0.003	0.006	0.0015	0.0014	0.013	0.013	0.005	0.016
Rank	3	5	2		6.5	6.5	4	
Score	53	62	31.5	33	37	47	44.5	
Overall Rank	6	7	1	2	3	5	4	

* NOTE: Rockville is not included in the ranking because of incomplete data.

TABLE 13

FINISHED WATER MINERAL COMPARISONS

PARAMETER	WSSC POTOMAC	WSSC PATUXENT	WAD DALECARLIA	WAD McMILLAN	FCWA OCCOQUAN	FCWA OLD LORTON	FCWA NEW LORTON	ROCKVILLE**
Sulfate (mg/l SO_3)	41.7	11.9	38	41	28.7	28.7	31.3	51
Rank	7	1	5	6	2.5	2.5	4	
Chloride (mg/l Cl)	21.2	15.6	18.3	19.8	16.9	21.2	15.7	30
Rank	6.5	1	4	5	3	6.5	2	
Nitrate (mg/l N)	4.9	3.1	1.23	1.25	0.52	0.51	0.86	
Rank	7	6	4	5	2	1	3	
Total Dissolved Solids (TDS) (mg/l)	180	81	199	195	115.3*	101.5*	169.9*	
Rank	5	1	7	6	3	2	4	
Score with TDS	25.5	9	20	22	10.5	12	13	
Overall Rank with TDS	7	1	5	6	2	3	4	
Score without TDS	20.5	8	13	16	7.5	10	9	
Overall Rank without TDS	7	2	5	6	1	4	3	

* 1981 data only.
** NOTE: Rockville is not included in the ranking because of incomplete data.

TABLE 14

FINISHED WATER AESTHETIC COMPARISONS

PARAMETER	WSSC POTOMAC	WSSC PATUXENT	WAD DALECARLIA	WAD McMILLAN	FCWA OCCOQUAN	FCWA OLD LORTON	FCWA NEW LORTON	ROCKVILLE**
Color (Color Units)	0.8	0	<1	<1	10.9	11.4	10.5	0
Rank	3	1	3	3	5	6	4	
Odor*** (Odor Number)	1.20	1.02	-	-	15.5*	13.3*	14.0*	1.0
Rank								
Turbidity (JTU)	0.45	0.26	0.25	0.24	0.29	0.21	0.32	0.43
Rank	7	4	3	2	5	1	6	
Score	10	5	6	5	10	7	10	
Overall Rank	6	1.5	3	1.5	6	4	6	

* 1981 data only.
** NOTE: Rockville is not included in the rankings because of incomplete data.
*** NOTE: Odor not used in ranking because data not available.

TABLE 15

OVERALL QUALITY COMPARISONS FOR RAW WATER OVERALL RANKING

CATAGORY	WSSC POTOMAC	WSSC PATUXENT	WAD POTOMAC	FCWA OCCOQUAN
Metals	4	2	1	3
Mineral	4	1.5	3	1.5
Aesthetic	3	1	3	3
Score	11	4.5	7	7.5
Overall Rank	4	1	2	3

TABLE 16

OVERALL QUALITY COMPARISONS FOR FINISHED WATER OVERALL RANKING

CATAGORY	WSSC POTOMAC	WSSC PATUXENT	WAD DALECARLIA	WAD McMILLAN	FCWA OCCOQUAN	FCWA OLD LORTON	FCWA NEW LORTON
Metals	6	7	1	2	3	5	4
Mineral	7	2	5	6	1	4	3
Aesthetic	6	1.5	3	1.5	6	4	6
Score	19	10.5	9	9.5	10	13	13
Overall Rank	7	4	1	2	3	5.5	5.5

COMPARISON OF RAW AND FINISHED WATER TO DRINKING AND SURFACE WATER STANDARDS

The quality of the finished water of the MWA supply systems was compared to existing drinking or surface water standards. This was done by using grand averages of the historical data. The grand average was divided into the standard. A ratio greater than one indicates the value is within standards and the larger the value of the ratio over one, the greater the safety margin before the parameter reaches the standard limit. The results are summarized in Tables 17 through 20.

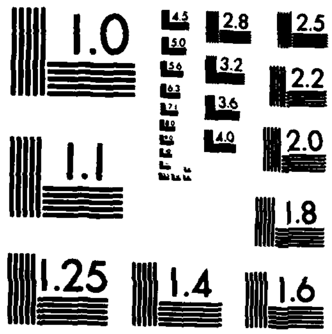
It is seen that except for iron and managanese levels in the Potomac River and odor levels in the Occoquan, all parameters fall within existing limits.

AD-A134 159 METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY APPENDIX G NON-STRUCTURAL STUDIES(U) CORPS OF ENGINEERS BALTIMORE MD BALTIMORE DISTRICT SEP 83 MWA-83-P-APP-G 5/5

UNCLASSIFIED F/G 13/2 NL

END

FILMED



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE 17

RAW WATER QUALITY COMPARED TO SURFACE WATER CRITERIA FOR METALS
(Ratio = value/standard)

PARAMETER STANDARD (mg/1)	WSSC POTOMAC	WSSC PATUXENT	WAD POTOMAC	FCWA OCCOQUAN	ROCKVILLE
Fe 0.3	0.43	0.79	0.42	0.50	2.59
Mn 0.05	0.43	0.41	0.77	0.32	0.25
Cu 1.0	8.26	18.87	66.7	32.3	3.7
As 0.05	25.0	25.0	25.0	8.3	-
Pb 0.05	2.3	2.8	25.0	12.5	-
Se 0.01	11.1	11.1	3.3	5.0	-
Ag 0.05	16.7	25.0	83.3	125.0	-
Zn 5.0	82.0	23.4	312.5	2500.0	41.7
Cd 0.01	5.0	5.0	16.7	16.7	-
Cr 0.05	12.5	16.7	12.5	3.6	12.5

TABLE 18

RAW WATER QUALITY COMPARED TO SURFACE WATER CRITERIA
FOR MINERALS AND ASTHETICS
(Ratio = value/standard)

PARAMETER STANDARD (mg/1) (Units)	WSSC POTOMAC	WSSC PATUXENT	WAD POTOMAC	FCWA OCCOQUAN	FCWA POTOMAC	ROCKVILLE
Sulfate 250	7.3	33.3	8.6	14.9	4.6	-
Chloride 250	17.0	22.5	17.4	21.0	15.1	11.4
Nitrate 10 as N	2.0	2.7	7.5	17.9	12.5	-
TDS 500	2.7	8.3	2.7	5.8	4.4	-
Color 75	10.2	17.5	-	1.5	-	-

TABLE 19

FINISHED WATER QUALITY COMPARED TO STANDARDS FOR METALS
(Ratio = value/standard)

PARAMETER STANDARD (mg/1)	WSSC POTOMAC	WSSC PATUXENT	WAD DALECARLIA	WAD McMILLAN	FCWA OCCOQUAN	FCWA OLD LORTON	FCWA NEW LORTON	ROCKVILLE
Fe 0.3	4.16	5.08	11.53	7.69	18.75	3.49	5.55	4.6
Mn 0.05	2.00	2.50	7.14	6.25	8.33	7.14	16.67	1.7
Cu 1.0	62.5	30.3	166.7	23.8	125.0	111.1	125.0	5.8
As 0.05	50.0	5.0	50.0	71.4	8.3	8.3	8.3	-
Pb 0.05	1.6	4.5	50.0	35.7	12.5	12.5	8.3	-
Hg 0.002	20.0	4.0	10.0	20.0	4.0	4.0	6.7	-
Se 0.01	12.5	16.7	5.0	5.0	5.0	5.0	3.3	-
Ag 0.05	12.5	25.0	125.0	250.0	250.0	250.0	166.7	-
Zn 5.0	102.0	49.5	515.5	416.7	16666.6	1666.5	1250.0	23.8
Cd 0.01	2.5	1.7	25.0	33.3	25.0	25.0	16.7	-
Cr 0.05	16.7	8.3	33.3	35.7	3.8	3.8	10.0	3.1

TABLE 20

FINISHED WATER QUALITY COMPARED TO STANDARDS FOR MINERALS AND ASTHETICS
(Ratio = value/standard)

PARAMETER	WSSC POTOMAC	WSSC PATUXENT	WAD DELECARLIA	WAD McMILLAN	FCWA OCCOQUAN	FCWA OLD LORTON	FCWA NEW LORTON	ROCKVILLE
Sulfate 250 mg/1	6.0	21.0	6.6	6.1	8.7	8.7	8.0	5.0
Chloride 250 mg/1	11.8	16.0	13.7	12.6	14.8	11.8	15.9	8.3
Nitrate 10 mg/1	2.0	3.2	8.1	8.0	19.2	19.6	11.6	-
TDS 500 mg/1	2.8	6.2	2.5	2.6	4.3	4.9	2.9	-
Color 15	18.8	>1000	-	-	1.4	1.3	1.4	>1000
Odor 3	2.5	2.9	-	-	0.19	0.22	0.21	3.0
Turbidity 1	2.2	3.8	4.0	4.2	3.4	4.8	3.1	2.3

COMPARISON OF PLANT FLEXIBILITY

The ability of the MWA plants to adjust to changing flows and water quality is addressed in this section. As in the case of comparing water quality, the comparison of plant flexibility is difficult to do in a quantitative way. Unfortunately, a detailed engineering analysis was not possible at this level of effort. Thus, an alternate route was selected, and, although somewhat subjective, it was possible to develop a relative ranking system and to gain insight into capabilities available to cope with changing flow and water quality conditions. From available information, a set of criteria was selected that incorporates different areas of process control and adjustment within the treatment facilities. The criteria used to evaluate plant flexibility includes such parameters as excess capacity, chemical storage and treatment, the process units themselves and general plant flexibility. This last factor takes into consideration points such as the age and overall conditions of the plant, laboratory capabilities, instrumentation, and sludge handling schemes.

With the exception of the McMillan WTP (WAD), all plants were visited by TSD staff during June of 1982. The evaluations consider the plant's condition at that time; however, the WSSC Patuxent plant and the WAD McMillan plant were at that time and are currently undergoing extensive renovations. These modifications will greatly improve the flexibility of these plants. For instance, at the Patuxent WTP a new chemical building has recently been constructed and is due to come on-line in the Fall of 1982. This new facility will enable plant personnel to store chemicals in bulk and provide much greater flexibility in the feeding of these chemicals. In addition, plant operations will be enhanced at Patuxent by the renovation of the actual treatment units. Variable speed flocculation devices are being added along with improved baffling and effluent launderers in the sedimentation basins. The existing filters are being converted to dual or mixed-media with surface wash and improved monitoring instrumentation is also being added. At McMillan, the existing slow sand filters are being replaced by rapid sand filters plus other modifications.

The numbers shown in Table 21 reflect the evaluator's judgement of several plant flexibility parameters. A value of 5, 7, or 10 was assigned to indicate whether that particular parameter was judged to be fair, good, or excellent from the standpoint of flexibility. These values were then totaled for each category (e.g., capacity) for each plant. A ranking, 1 through 9, was then assigned based on the total score that plant received in that particular category. In the case of equal scores, the evaluator subjectively determined the rank based on his inspection of that plant. The final rankings are summarized in Table 22.

Table 22 shows that the FCWA Potomac WTP received the best rating (lowest number). This plant is the newest and most modern plant in the MWA. The WSSC Potomac plant and the WAD Dalecarlia plant received the next highest ratings in terms of flexibility. Rockville, the smallest plant evaluated was ranked seventh followed by the WSSC Patuxent plant and the WAD McMillan plant (the oldest plant). As was noted earlier, both the Patuxent and McMillan plants are being renovated and it is expected that these modifications will greatly improve their flexibility to treat water. In fact, plant personnel have indicated that the flexibility of these two plants should be comparable with the other plants within their authorities (WSSC Potomac and WAD Dalecarlia) when the renovations are complete.

All plants had a capability to adjust and control the treatment process to accommodate degradation of source quality below that which is currently encountered. However, without a more detailed engineering study and detailed analysis of future water quality trends it is impossible to make quantifiable statements about the long term (30 years) conditions. It does appear that there should be no difficulty for the facilities to deal with the short term (5 years) possibility of degrading water quality.

TABLE 21

PLANT FLEXIBILITY

	WSSC		WAD		FCWA				
Flexibility Parameter	Potomac	Patuxent	Dalecarlia	McMillan	Occoquan	Old Lorton	New Lorton	Potomac	Rockville
CAPACITY									
Excess Cap.[a]	10	7	7	7	7	7	5	10	10
Intake Structure	10	5	7	7	7	7	7	10	7
Raw Pumps	10	7	10	7	7	7	7	10	7
Filter Cap.	10	5	10	5	7	7	10	10	7
Clearwell Cap.	7	10	10	10	5	5	5	7	5
TOTAL PTS.[b]	47	34	44	36	33	33	34	47	36
RANKING[c]	2	7	3	4	8	9	6	1	5
CHEMICAL TREATMENT									
Feeders	10	5	10	5	7	7	7	10	7
Alt. Chem.	10	5	10	5	7	7	7	10	7
PAC	10	7	10	5	10	10	10	10	7
Disinfect.	10	5	7	5	7	7	7	10	7
TOTAL PTS.	40	22	37	20	31	31	31	40	28
RANKING	1	8	3	9	5	6	4	2	7
CHEMICAL STORAGE									
Storage Cap.	10	5	10	5	5	7	7	10	7
Feed Equp.	10	5	10	5	7	7	7	10	7
Storage Form	10	5	10	5	7	10	10	10	10
TOTAL PTS.	30	15	30	15	19	24	24	30	24
RANKING	3	8	2	9	7	5	4	1	6

TABLE 21 Cont'd.

PLANT FLEXIBILITY

Flexibility Parameter	WSSC Potomac	WSSC Patuxent	WAD Dalecarlia	WAD McMillan	FCWA Occoquan	FCWA Old Lorton	FCWA New Lorton	FCWA Potomac	Rockville
PROCESS UNITS									
Rapid Mix	10	5	7	5	7	7	10	10	5
Flocculation	7	5	7	5	7	5	7	10	5
Sedimentation	7	5	7	5	7	5	7	10	7
Filtration	10	5	7	5	7	7	10	10	7
TOTAL PTS.	34	20	28	20	28	24	34	40	24
RANKING	3	8	4	9	5	7	2	1	6
GENERAL FLEXIBILITY									
Lab	10	7	10	5	5	7	7	10	5
Oper.	10	7	10	7	7	7	10	7	7
Age & Cond.	10	5	10	5	7	5	7	10	5
Instrumentation	7	5	7	5	7	7	7	10	7
Corrosion Cont.	7	7	7	7	7	7	7	7	7
Sludge Handling	5	7	5	5	5	7	7	10	5
TOTAL PTS.	49	38	49	34	38	40	45	54	36
RANKING	2	7	3	9	6	5	4	1	8

a. Numbers in table (5, 7 or 10) refer to relative flexibility of particular parameter with 10 being the highest rating.
b. Sum of the individual ratings for each plant.
c. Relative ranking of plant relative to other 8 plants with 1 being the highest ranking. (See narrative (p. 62) for discussion of treatment of the total point scores.)

TABLE 22

PLANT FLEXIBILITY RANKING SUMMARY

Flexibility Parameter	WSSC Potomac	WSSC Patuxent	WAD Dalecarlia	WAD McMillan	FCWA Occoquan	FCWA Old Lorton	FCWA New Lorton	FCWA Potomac	Rockville
Capacity	2	7	3	4	8	9	6	1	5
Chemical Treatment	1	8	3	9	5	6	4	2	7
Chemical Storage	3	8	2	9	7	5	4	1	6
Process Units	3	8	4	9	5	7	2	1	6
General Flexibility	2	7	3	9	6	5	4	1	8
TOTAL	11	38	15	40	31	32	20	6	32
RANKING	2	8*	3	9*	5	6	4	1	7

* See Narrative

INTERCONNECTIONS AND REREGULATION

The use of raw and finished water interconnections to satisfy water demand during drought conditions will result in periodically introducing water from different sources into existing distribution systems. This already occurs when the procedure of reregulation is employed. There are a variety of problems that can result from processing a different water through a treatment facility, blending with a different finished water before entering the distribution system, and mixing different water in the distribution system. These problems range from possible taste, odor, color, and particulate changes which produce consumer complaints to changes in corrosivity which can damage the distribution system and consumer plumbing.

The effects of changing sources are difficult to predict due to the very complex nature of the initial equilibria involved, the many factors which influence water quality, and the time dependency of changes within the system. Not only is the water chemistry complicated but such factors as the materials used in construction, the historical exposure of the system to the original water, and the frequency and magnitude of source changes must also be considered.

A number of fairly simple corrosion indices (Langelier, Ryznar, Riddick, etc.) have been developed to predict some of these effects but are limited in ability to do so. As pointed out by Gardels, "Corrosion Indices are valuable guides when used within their limitations. A universal method of predicting corrosion of all possible pipe surfaces based on water quality still remains to be found" (6). According to Patterson, "The difficulty associated with monitoring and controlling corrosivity is that there are no simple, generally accepted means for measuring the corrosivity of water, and thus the profession lacks a generally accepted numerical index or parameter for identifying and limiting corrosivity. There are a number of indices in use, but no agreement on a single one which would, in all cases, definitively identify corrosivity. Further, most of these indices were developed through laboratory investigations, and the identification of corrosivity and its response to passivation measures is vastly more simple in a closely controlled laboratory environment than in a full-scale water distribution system" (7).

Some general observations on the potential problems have been reported. Ainsworth, for example, presents a hierarchy of types of source change and the problems that are likely to produce long-term consumer complaints (8). In the following list (a) is less likely to produce long-term consumer complaints than is (f):

(a) Infrequent and brief source changes during emergencies such as a burst main or treatment failure.

(b) Blending old and new supplies in a constant proportion before entering the distribution system.

(c) Complete replacement of an old supply.

(d) Blending old and new supplies in varying proportions before entering the distribution system.

(e) Mixing old and new supplies within the distribution system.

(f) The conjunctive use of supplies where one routinely replaces another at regular intervals.

He also points out that water quality changes and customer complaints occur as the existing "equilibrium" chemistry is disrupted by source change. Thus a water supply with frequent and continued changes can be expected to have more problems than one with less frequent changes.

REREGULATION

Reregulation is the term used to identify a procedure to maintain reservoir storage at maximum for use during time of low river flow and high demands. The procedure can be used if a distribution system is supplied with treated water from both a river supply and a reservoir supply. During times of adequate river flow, the distribution system can be fed preferentially with treated water from the river supply thus reducing the demand on the reservoir supply. This strategy allows the reservoir to fill or maintain volume for future demands. If the river flow then becomes inadequate, the reservoir supply is then preferentially used to supply treated water to the distribution system. For the MWA, there are two major reregulation systems, the WSSC Potomac-Patuxent system and the FCWA Occoquan-Potomac system. Details of proposed operation are discussed in detail in "Appendix E - "R--- and Finished Water Interconnections and Reregulation" of the MWA study.

Effects on the quality of finished water delivered to the consumer due to reregulation are difficult to evaluate. They arise out of two different mechanisms. The first is the effect of reregulation on the quality of the reservoir supply and the second is the effect of blending different water in the distribution system.

As pointed out earlier, a quantitative assessment of the effects of blending different waters in the distribution system is complex and beyond the scope of this effort. Comparing finished water rankings for the WSSC Potomac-Patuxent reregulation system shows that the results for the metals category are not very different with the Potomac water being of slightly better quality. For the mineral category, the results show that the Patuxent water ranks near the best while the Potomac ranks as the poorest. Results for the aesthetics category show that the Patuxent

is moderately better than the Potomac. Thus, greatest differences occur in the mineral category. Data is not yet sufficiently developed from the new FCWA Potomac Plant to compare water quality for this reregulation system.

According to the hierarchy presented by Ainsworth, reregulation most closely aligns to category (e) - mixing old and new supplies within the distribution system. This category is the second most likely source of long-term consumer complaints. As he also points out, the more frequent the changes in supply are, the more frequent the problems are. Certainly then, in principle, the system should be managed with one objective being the minimization of changes consistent with maintaining an adequate supply of water. The weight of this factor in the optimization process will have to be established from a detailed study and analysis and/or experience.

The water quality of the reservoir will probably not be severely impacted because it is being supplied by its normal water. In addition, generally the time when there is water available in the river is also the time when the quality of water entering the reservoir is best. This promotes a better quality of stored water. Another positive factor is that generally, the closer a reservoir is to being full, the better its water quality. On the negative side, reregulation results in longer reservoir detention times which tend to allow greater algal growth and bacterial action resulting in increased potential for taste and odor problems and possibly higher filtration costs. On balance, the water quality of the Occoquan and Patuxent reservoirs probably will not be greatly affected by reregulation beyond the ordinary variations of the supply or the ability of the treatment facilities to treat with little change in finished quality.

FINISHED WATER INTERCONNECTIONS

Finished water interconnections involve the piping and pumping capacity to transfer finished water from one treatment facility to the distribution system of another. The consequences on water quality in the distribution system are very similar to those discussed in the sections on reregulation. For this situation, however, the hierarchical potential for customer complaints as expressed by Ainsworth falls somewhere between class (b) and (d). That is, between "blending old and new supplies in a constant proportion before entering the distribution system" and "blending old and new supplies in varying proportions before entering the distribution system." Thus, according to Answorth, finished water interconnections have less potential for producing consumer complaints than does the procedure of reregulation.

There are two finished water interconnections considered in this report. The first is a reversible interconnection between the WAD Dalecarlia facility and the WSSC Potomac system. The second is a reversible interconnection between WAD Dalecarlia facility and the FCWA Potomac Plant. Based on the ranking results, the Dalecarlia finished water appears to be of slightly better quality than the WSSC Potomac water. Data is not yet available to compare the FCWA Potomac facility quality to the Dalecarlia quality. However, based on the fact that the finished waters are not strongly different and the Potomac River is the common raw water source, the blending effects should be minor.

RAW WATER INTERCONNECTIONS

There are two raw water interconnections considered. The first is the reversible WSSC Potomac/Patuxent (Rocky Gorge Reservoir) interconnection. The second is the reversible interconnection between the FCWA Potomac Plant and the Occoquan Reservoir.

A study was done in 1978 by Enviro Plan, Inc., on the effects of raw water interconnections on water quality (9). The study contains the results of computer simulations used to evaluate the effects of raw water interconnections pumping in either direction. Baseline data for the Potomac - Rocky Gorge and the Potomac - Occoquan interconnections is shown in Tables 23 through 26. The effect of pumping Rocky Gorge Reservoir water to the Potomac River (using the baseline data) is summarized in Table 27. It is clearly seen that under each scenario, the mixed parameter values in the river ("final" column) are little different than the values in the river before mixing. Thus, the effects are minimal at worst and negligible at best. A similar conclusion is established from the predicted effects of pumping Occoquan Reservoir water to the Potomac River as shown in Table 28.

Effects of pumping Potomac water into Rocky Gorge Reservoir were not summarized in tabular form but in narrative and graphical form. A summary of the results of Enviro Plan's analysis follows. (All results are based on a complete mixing model.)

> Nitrate (As N) - The only scenario that produces excursions of nitrate concentrations greater than the normal range of variation in the Rocky Gorge Reservoir is with maximum nitrate concentrations in both Rocky Gorge and Potomac water. This scenario yields a maximum concentration in Rocky Gorge of 2 mg/l greater than the maximum observed nitrate concentration (4.6 mg/l). All other

scenarios yield nitrate concentrations less than the maximum observed Rocky Gorge nitrate concentration. If both waters contain average concentrations of nitrate, the maximum value of Rocky Gorge Reservoir water is predicted to be 1.5 mg/l which is close to the observed Rocky Gorge average of 1.2 mg/l. This would be the expected or most likely combination.

Ammonia - Assuming both waters at maximum observed ammonia concentrations, the admixture will have a concentration 0.07 mg/l above the Rocky Gorge baseline value. This is a negligible change.

Total Phosphorous (as P) - There is a wide variation in phosphorous concentrations observed in Rocky Gorge Reservoir water with the maximum value being 1.0 mg/l. The maximum observed for Potomac water was 0.88 mg/l. Mixing waters with average phosphate concentrations results a concentration of 0.13 mg/l which is twice the Rocky Gorge baseline level. Other scenarios produce some values for phosphorous greater than baseline but less than the observed Rocky Gorge maximum. This is due to the fact that the Rocky Gorge maximum is greater than the Potomac maximum.

Total Dissolved Solids (TDS) - Since the Potomac River TDS concentrations run about twice those for Rocky Gorge Reservoir all mixing scenarios result in some TDS values greater than the maximum TDS value observed in the reservoir. Mixing average waters would result in reservoir TDS values outside the normal range for six months of the year. Under maximum concentration mixing, the TDS levels in the reservoir approach twice the maximum normal values observed in the reservoir.

Total Alkalinity - All four mixing scenarios will result in total alkalinity levels in the reservoir outside the range normally observed. Mixing waters of average alkalinity will result an alkalinity range of 23 to 42 mg/l compared to a level of 18 mg/l normally found in Rocky Gorge.

Total Hardness (as $CaCO_3$) - All mixing scenarios result in values greater than the normal range of 21-23 mg/l for Rocky Gorge for the entire year.

The findings related to the two raw water interconnections considered here are:

1) The concentrations of phosphorous, inorganic nitrogen, and total alkalinity are generally higher in the Potomac River than in the Rocky Gorge and Occoquan Reservoirs.

2) Both reservoirs would experience an increase in total alkalinity concentrations as a result of the interconnections.

3) The Potomac River - Rocky Gorge Reservoir interconnection could cause increased entrophication in Rocky Gorge due to projected increases in nutrients, especially phosphorus.

4) Under the conditions of the hydrologic scenario, Occoquan Reservoir water quality would probably not be significantly impacted by the Potomac River - Occoquan interconnection.

5) Increases in alkalinity and nutrient availability resulting from input of piped Potomac River could cause increases in treatment costs at the filtration plants. These costs are related to more frequent filter backwashing and the need for greater quantities of coagulants.

6) Neither of the interconnections are expected to cause violations of existing Federal, State, or local water quality standards.

7) The water quality effects of pumping reservoir water to the Potomac River are minimal.

Data comparison between this study and the Enviro Plan study is severely limited because only total dissolved solids and nitrate nitrogen are at least partially common to both baseline data sets. The total dissolved solids for the Potomac - Rocky Gorge interconnection show that there is little difference between the two studies (for this study, total dissolved solids baseline values are 188 mg/l for the Potomac and 60 mg/l for Rocky Gorge, while the Enviro Plan report values are 207 for the Potomac and 61 for Rocky Gorge). The nitrate nitrogen values are higher in this report than in the Enviro Plan study by factors of between two and three. This study shows nitrate nitrogen for the Potomac to be 4.9 mg/l and for Rocky Gorge to be 3.7 mg/l while the Enviro Plan values are 1.88 and 1.19 mg/l, respectively. For the Potomac - Occoquan interconnections, this report yields a value for the Occoquan Reservoir of 0.56 mg/l. Corresponding values for the new Potomac Intake are not yet available. The Enviro Plan results are 1.74 mg/l for the Potomac and 0.323 for the reservoir. Again, it appears that the nitrate nitrogen values are higher in this report. However, in the case of the Potomac - Occoquan interconnection, the ratio of Potomac to Rocky Gorge nitrogen is 1.59 using the Enviro Plan data and 1.35 using data from this report. Thus, while there seems to be higher values of nitrate nitrogen concentrations in this study, the ratios show a lesser potential affect because the differences are relatively smaller. Considering the Enviro Plan conclusions and the raw water rankings of this study, it is seen that the general water quality of Rocky Gorge will tend to be degraded by pumping Potomac water into it. Although this problem is compounded by the fact that the WSSC Patuxent plant is one of the least flexible of the area plants in providing treatment, current renovation plans should increase the flexibility of this facility to a level comparable to the other plants.

Since any mixture of the different waters will not result in source water which would not be treatable or result in a finished water that exceeds existing standards, there should be no problem for the Patuxent plant to treat the mixture resulting from the Potomac - Rocky Gorge Raw Water Interconnection except for some possible increase in cost. Renovations made at the Patuxent plant will improve the capability to upgrade the finished product.

The Enviro Plan results for the FCWA Potomac - Occoquan show increases in both nitrogen and phosphorous concentrations in the Occoquan Reservoir. These increases will contribute to increased algal growth. However, as pointed out by the study, it is difficult to predict how significant the impact will be. Again, since data from the new FCWA Potomac plant is not available, inferences in this study are made from Potomac water as profiled by data from the WSSC and WAD Potomac intakes. Generally, the overall water quality for the metals comparisons while rankable is not clearly different. Thus, no inference other than there should be minimal changes in the overall metals water quality. The overall comparisons in the mineral quality show that Occoquan water will be somewhat degraded. In terms of aesthetic comparisons, Occoquan water should have improved in color and odor levels but degraded turbidity levels. Overall, the changes should not be great enough to cause problems in treating except for potential increased algal production leading to higher costs and possibly increased taste and odor complaints.

TABLE 23

BASELINE WATER QUALITY IN POTOMAC RIVER AND OCCOQUAN RESERVOIR*

VALUES FOR OCCOQUAN RESERVOIR (EXCEPT TOTAL ALKALINITY) GENERATED BY HSP SIMULATION WITH NO INPUT FOR PIPELINE PUMPING. TOTAL ALKALINITY VALUES FOR POTOMAC ARE FROM WSSC POTOMAC FILTRATION PLANT; OTHER PARAMETERS FROM STORET STATIONS 15001.8, 15001.4, 15001.0, MC SITE SVY P12, P12, AND POT-CONS-D12, ALL IN THE VICINITY OF LOWES ISLAND (SITE OF PROPOSED PIPELINE). TOTAL ALKALINITY VALUES FOR OCCOQUAN FROM BASIN-WIDE COMPILATION. ALL VALUES IN mg/l, UNLESS OTHERWISE NOTED.

Parameter	Potomac River			Occoquan Reservoir					
				Epilimnion			Hypolimnion		
	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
BOD, ultimate	0.15	4.84	14.56	0.29	1.60	6.7	0.13	2.23	6.75
Organic N (as N)	0.47	0.61	0.86	0.023	0.154	0.829	0.023	0.221	0.887
NO_2 & NO_3 (as N)	0.001	1.74	3.60	0.022	0.323	0.655	0.0	0.318	0.659
NH_3 (as N)	0.001	0.049	0.141	0.002	0.037	0.129	0.022	0.221	0.699
Ortho-P (as P)	0.003	0.019	0.077	0.002	0.017	0.077	0.010	0.036	0.056
Organic-P (as P)	0.006	0.074	0.400	0.001	0.015	0.051	0.002	0.024	0.075
Chlorophyll a (mg/l)	-	-	-	0.062	6.55	29.2	-	-	-
Total P Accum. (lbs)	-	-	-	-	-	-		16,000	
Biomass Settled (lbs)	-	-	-	-	-	-		55,800	
Total Alkalinity (as $CACO_3$)	47	70	110	10	32	55	10	32	55

* From "Water Quality Impacts of Proposed Raw Water Interconnections in the Metropolitan Washington Area," Enviro Plan, Inc., April 1979.

TABLE 24

BASELINE WATER QUALITY IN POTOMAC RIVER AND ROCKY GORGE RESERVOIR*

BASED ON WSSC MONTHLY AVERAGE DATA
ALL VALUES IN mg/l

Parameter	Potomac River			Rocky Gorge Reservoir		
	Minimum	Average	Maximum	Minimum	Average	Maximum
NO_3 (as N)	0.20	1.88	5.69	0.10	1.19	4.61
NH_3 (as N)	0.01	0.16	0.6	0.02	0.15	0.41
Total P (as P)	0.06	0.22	0.88	0.01	0.065	1.0
Total Dissolved Solids	122	207	414	39	61	99
Total Alkalinity (as $CaCO_3$)	47	70	110	13	18	25
Total Hardness (as $CaCO_3$)	76	105	152	21	26	32

* From "Water Quality Impacts of Proposed Raw Water Interconnections in the Metropolitan Washington Area," Enviro Plan, Inc., April 1979.

TABLE 25

STATISTICAL SUMMARY OF SIMULATED WATER QUALITY PARAMETERS IN THE EPILIMNION OF THE OCCOQUAN RESERVOIR UNDER THE HYDROLOGIC CONDITIONS OF APRIL 1930 TO MARCH 1931 FOR THE POTOMAC-OCCOQUAN INTERCONNECTION[+]

Constituent	Indicator	Baseline* Conditions	Pumping** Minimum Concentrations	Pumping*** Average Concentrations	Pumping**** Maximum Concentrations
BOD Ultimate (mg/l)	Max	6.71	6.75	6.75	6.75
	Min	0.29	0.2	0.59	0.78
	Mean	1.60	1.8	2.0	2.4
Dissolved Oxygen (mg/l)	Max	14.5	14.6	14.6	14.9
	Min	9.5	7.8	7.6	7.2
	Mean	11.4	11.2	11.2	11.1
Ammonia (as N) (mg/l)	Max	0.129	0.310	0.395	0.496
	Min	0.002	0.002	0.002	0.002
	Mean	0.037	0.067	0.077	0.093
Nitrate (as N) (mg/l)	Max	0.655	0.578	1.17	1.93
	Min	0.022	0.022	0.022	0.022
	Mean	0.323	0.278	0.462	0.656
Organic Nitrogen (as N) (mg/l)	Max	0.829	0.831	0.831	0.831
	Min	0.023	0.051	0.061	0.051
	Mean	0.154	0.170	0.178	0.191
Organic Phosphorus (as P) (mg/l)	Max	0.077	0.077	0.077	0.077
	Min	0.002	0.003	0.006	0.006
	Mean	0.017	0.017	0.020	0.028
Orthophosphorus (as P) (mg/l)	Max	0.051	0.046	0.051	0.077
	Min	0.001	0.001	0.001	0.001
	Mean	0.015	0.017	0.018	0.023
Total Phosphorus (as P) (mg/l)	Max	0.100	0.100	0.100	0.113
	Min	0.008	0.008	0.008	0.008
	Mean	0.031	0.034	0.037	0.052

[+] From "Water Quality Impacts of Proposed Raw Water Interconnections in the Metropolitan Washington Area," Enviro Plan, Inc., April 1979.

* Scenario #1: Baseline Reservoir Conditions.

** Scenario #2: Reservoir Conditions When Pumping in Minimum Constituent Concentrations from the Potomac River.

*** Scenario #3: Reservoir Conditions When Pumping in Average Constituent Concentrations from the Potomac River.

**** Scenario #4: Reservoir Conditions When Pumping in Maximum Constituent Concentrations from the Potomac River.

TABLE 26

STATISTICAL SUMMARY OF SIMULATED WATER QUALITY PARAMETERS IN THE HYPOLIMNION OF THE OCCOQUAN RESERVOIR UNDER THE HYDROLOGIC CONDITIONS OF APRIL 1930 TO MARCH 1931 FOR THE POTOMAC-OCCOQUAN INTERCONNECTION[+]

Constituent	Indicator	Baseline* Conditions	Pumping** Minimum Concentrations	Pumping*** Average Concentrations	Pumping**** Maximum Concentrations
BOD Ultimate (mg/l)	Max	6.75	6.09	6.09	6.09
	Min	0.13	0.12	0.34	0.73
	Mean	2.23	2.06	2.96	3.16
Dissolved Oxygen (mg/l)	Max	11.7	11.9	11.5	11.1
	Min	0.0	0.0	0.0	0.0
	Mean	5.0	4.8	4.7	4.4
Ammonia (as N) (mg/l)	Max	0.699	0.746	0.931	1.130
	Min	0.022	0.022	0.022	0.022
	Mean	0.221	0.331	0.348	0.372
Nitrate (as N) (mg/l)	Max	0.659	0.588	1.17	1.91
	Min	0.000	0.000	0.000	0.000
	Mean	0.318	0.242	0.402	0.571
Organic Nitrogen (as N) (mg/l)	Max	0.887	0.889	0.889	0.889
	Min	0.023	0.076	0.083	0.092
	Mean	0.221	0.266	0.270	0.277
Organic Phosphorus (as P) (mg/l)	Max	0.075	0.075	0.075	0.075
	Min	0.002	0.003	0.003	0.012
	Mean	0.024	0.028	0.030	0.040
Orthophosphorus (as P) (mg/l)	Max	0.056	0.067	0.068	0.077
	Min	0.010	0.010	0.010	0.010
	Mean	0.036	0.043	0.045	0.051
Total Phosphorus (as P) (mg/l)	Max	0.107	0.107	0.108	0.134
	Min	0.024	0.044	0.044	0.044
	Mean	0.060	0.072	0.075	0.091

[+] From "Water Quality Impacts of Proposed Raw Water Interconnections in the Metropolitan Washington Area," Enviro Plan, Inc., April 1979.

* Scenario #1: Baseline Reservoir Conditions.

** Scenario #2: Reservoir Conditions When Pumping in Minimum Constituent Concentrations from the Potomac River.

*** Scenario #3: Reservoir Conditions When Pumping in Average Constituent Concentrations from the Potomac River.

**** Scenario #4: Reservoir Conditions When Pumping in Maximum Constituent Concentrations from the Potomac River.

TABLE 27

EFFECT OF PUMPING ROCKY GORGE RESERVOIR WATER TO POTOMAC RIVER*

SIMULATIONS DONE BY RIVER MASS BALANCE, USING CONDITIONS
OCCURRING DURING AUGUST 1930 OF THE HYDROLOGIC SCENARIO
RIVER FLOW = 705 mgd; PUMPING RATE = 36 mgd
ALL VALUES IN mg/l

Parameter	RG_{avg} to POT_{avg}		RG_{max} to POT_{max}		RG_{min} to POT_{max}		RG_{max} to POT_{min}	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Nitrate (as N)	1.9	1.8	5.7	5.6	5.7	5.6	0.2	0.2
Ammonia (as N)	0.16	0.16	0.6	0.59	0.6	0.57	0.01	0.03
Phosphorus (as P)	0.22	0.21	0.88	0.89	0.88	0.84	0.06	0.11
Total Dissolved Solids	207	200	414	399	414	396	122	121
Total Alkalinity (as $CaCO_3$)	70	67	110	106	110	105	47	46
Total Hardness (as $CaCO_3$)	105	102	152	146	152	146	76	74

* From "Water Quality Impacts of Proposed Raw Water Interconnections in the Metropolitan Washington Area," Enviro Plan, Inc., April 1979.

TABLE 28

EFFECT OF PUMPING OCCOQUAN RESERVOIR WATER TO POTOMAC RIVER*

SIMULATIONS DONE BY RIVER MASS BALANCE; CONCENTRATIONS FOR OCCOQUAN SUPPLIED BY HSP MODEL
FOR CONDITIONS OCCURRING DURING AUGUST 1930 OF THE HYDROLOGIC SCENARIO
RIVER FLOW = 705 mgd; PUMPING RATE = 54 mgd
ALL VALUES IN mg/l

Parameter	Piped Water From Occoquan Epilimnion	Potomac River					
		Minimum	After Pumping	Average	After Pumping	Maximum	After Pumping
BOD, ultimate	1.03	0.15	0.21	4.84	4.57	14.6	13.6
Organic N (as N)	0.06	0.47	0.61	0.57	0.86	0.86	0.80
NO_2 & NO_3 (as N)	0.26	0.001	0.019	1.7	1.6	3.6	3.4
NH_3 (as N)	0.01	0.001	0.002	0.049	0.046	0.14	0.13
Ortho-P (as P)	0.002	0.003	0.003	0.019	0.018	0.077	0.072
Organic-P (as P)	0.009	0.006	0.006	0.074	0.069	0.40	0.37
Total P (as P)	0.011	0.009	0.009	0.093	0.087	0.477	0.442

* From "Water Quality Impacts of Proposed Raw Water Interconnections in the Metropolitan Washington Area," Enviro Plan, Inc., April 1979.

RENOVATED WASTEWATER - EXPERIMENTAL ESTUARY TREATMENT PLANT

One proposed method of augmenting water supply in the Potomac River is to reclaim Potomac River estuary water (which receives treated wastewater) through an estuary treatment plant. The evaluation of the feasibility of this concept is now being conducted with a pilot experimental estuary water treatment plant (EEWTP) completed by the Army Corps of Engineers, Baltimore District, in early 1980. A contract for a three-year program for operation, maintenance, and performance evaluation of the demonstration plant was made with James M. Montgomery, Consulting Engineers, Inc., in May 1980. The project objectives, stated in the form of key questions to be answered, are as follows with the overall objective being to determine the technical and economic feasibility of using the Potomac River estuary as a supplemental source of potable water in the MWA:

1. Using the best available analytical techniques, what quality of water can be produced by advanced water treatment processes?

2. Is the water produced by the demonstration plant of potable quality?

3. What are the optimum process combinations which will ensure production of potable water at a minimum cost?

4. Finally, what is the estimated cost of such a water treatment plant with a hydraulic capacity of 200 mgd?

Based on a review of the first (May 1980 - March 1981) and second (March 1981 - September 1981) progress reports submitted by James M. Montgomery, the experimental pilot plant project is well designed to meet the above objectives.

The viability of wastewater renovation as an alternative augmentation of the MWA water supply depends on at least three factors all relating to potability. The first is based on the fact that almost any raw water can be made potable if one wished to spend enough money. Thus, whether or not a Potomac estuary water contaminated with treated wastewater can be renovated to a potable level is not the issue. Rather, is it cost effective and practical to do so? According to Clark, et al., "renovated wastewater is extremely expensive as a solution" (10). Thus, it is important to evaluate this factor and it is expected that the pilot study will define the costs to the point necessary to determine the cost effectiveness.

The second factor is related to the difficulty of determining true potability. As has been pointed out earlier and as emphasized in the second Montgomery progress report, "meeting the EPA primary and secondary drinking standards cannot be considered sufficient evidence that the water produced by the EEWTP is acceptable for human consumption." Clark, et al., point out that "undefined health problems may be associated

with RWW [Renovated Waste Water] effluent." Thus, although a minimal approach to determining potability can be achieved, an absolute certainty is not possible and effluent from the EEWTP would remain suspect for some time.

This leads into the third factor which is the view that in addition to physical and chemical characteristics as definers of potability, psychological acceptance by the consumer is necessary before potability is achieved. In essence, if consumers will not drink the water, no matter how good, then for those consumers, the water is not potable. If they will drink the water but are uncomfortable in doing so, there is still a potability problem. The issue at this point is that there does not appear to be any studies currently being undertaken or planned to evaluate possible problems with MWA consumer acceptance of reclaimed human sewage as a source of drinking water. That this can be a significant and highly visible issue is evidenced by the Chanute, Kansas experience. Dwight Metzler, et al., described in a 1958 paper the results of using reclaimed wastewater in Chanute as an emergency supplement to the potable supply (11). Some of the statements and conclusions from the paper are:

- "…. the great majority of water consumers take a dim view of deriving all or any small part of their drinking water from the local sewage treatment plant effluent - regardless of the purification processes employed or the quality of the finished product."

- "There was an unprecedented awareness on the part of local residents and their neighbors in nearby communities of the innovation at Chanute and spectators from near and far visited the plant to observe its operation."

- "The high ammonia content of the raw water made free residual chlorination impractical for taste and odor control and complete color removal."

- "The water was unsuitable for most laboratory purposes. Even after double distillation it could not be used for making standard solutions or mixing reagents because of carry-over."

- "The treated water had several objectional characteristics. It had a pale color and an unpleasant musty taste and odor."

- "Initial public acceptance of the water was good, probably because the citizens knew that their supply normally received diluted treated sewage from seven upstream communities. No public mention of the move was made until after recirculation had been started. Public reaction became more adverse when stories appeared in the local newspapers. Bottled-water sales flourished and virtually all grocery stores carried a large stock."

- "More than 70 private wells were drilled…."

- "Consumer acceptance of the water was poor, and many persons obtained their drinking water from other sources."

- "The most serious problem is that of public acceptance or - more accurately - public rejection of the water...."

- "The reuse of sewage treatment plant effluent to supplement deficient water supplies should not be considered or permitted except under the most severe emergency conditions. It is certainly a last resort, to be used only after all other possible sources of supply have been fully investigated."

It should be clear from the above comments and conclusions that the attitudes of the consumer need to be assessed as well as some study of approaches that could be used to ameliorate acceptance or rejection problems.

In summary, although the EEWTP pilot study will provide the necessary information to determine if estuary water can be a cost effective alternative to augment the MWA water supply, there will remain concerns about undefined health problems and public acceptance.

POTABILITY OF OTHER SOURCES

The scope of work for this study also called for a comparative assessment of the potability/treatability aspects of other potential water supply sources to include selected upstream reservoirs (both in the MWA and in the Upper Potomac Basin) and the use of ground water. An examination of the existing data resulted in the conclusion that there was insufficient data available to compare the potential groundwater resources with the other potential sources. Similarly, the lack of water quality data on most of the upstream reservoir sites limits the scope of the analysis that can be conducted relative to the potability aspects of upstream storage.

Based on work by Sheer and Harris (12), a summary assessment of water quality as influenced by Bloomington and Savage Dams can be made. Water quality in the North Branch of the Potomac River tends to be poor because of coal mining related acid drainage. Two large reservoirs dominate the system. Savage River Reservoir (12 billion gallons) and Bloomington Reservoir (42 billion gallons). Savage Dam has a single base outlet and an uncontrolled spillway while Bloomington has a multiport outlet with five levels including an emergency spillway.

According to Sheer and Harris, "Bloomington Dam improves water quality downstream primarily by averaging the release of acid over time." However, they also point out, "This averaging must be accomplished within the constraints of the other purposes of the project: maintaining minimum flow, meeting water supply needs downstream at Washington, D.C., and providing flood control." Another element in water quality management is the effect that the Westernport wastewater treatment plant effluent has in neutralizing acid drainage. The authors have proposed procedures for defining proper reservoir operations. These procedures, however, will require gathering new data and developing simulation and optimization studies for the system.

The conclusions reached by Sheer and Harris are repeated here as follows:

1. Significant water quality improvement will occur downstream of Bloomington Dam because the reservoir will intercept and dilute slugs of highly acidic influent.

2. The wastewater treatment plant at Westernport exerts a neutralizing effect equivalent to about 13.6 metric tons of $CaCO_3$/d (15 tons/day). Some solid $CaCO_3$ from the pulp and paper mill effluent reacts with CO_2 and dissolves during secondary treatment, producing an effluent containing about 3mM bicarbonate.

3. A procedure for determining reservoir operations has been proposed. It attempts to maintain a consistent pH as high as possible over the long term. The formula relies on the newly defined functional acidity of each source of acid, as well as the conventional alkalinity of each source of base.

4. Functional acidity and alkalinity data must be accumulated to implement the operating rule.

5. Simulation and optimization studies for control of water quality in the reservoir and the river are desirable.

Future water quality of Little Seneca Lake was assessed in the report "Project Development Report on Little Seneca Lake for the Washington Surburban Sanitary Commission" (13). Seven models were used to predict algal growth, pH, ammonia, fecal coliforms, and temperature for current and future land use patterns and for various flow conditions. In addition, in Appendix A of the report, presents information on the water quality of streams that will flow into the reservoir. In general, the water quality parameters reported in the feeding tributaries are nominal and with the exception of an occasional sample are within state and EPA standards. One other exception is the fecal coliform values which tend to exceed the 200/100 ml state standard. However, the simulation studies indicate that coliform die off in the reservoir is such that the levels in the central pool and releases from the reservoir are within state and EPA standards.

Thus, it appears that there are no serious water quality problems to be anticipated for Little Seneca Lake.

SUMMARY AND CONCLUSIONS

Although there are differences in water supplies, treatment plants, and finished water quality, the results of this study do not show any situation where drinking water regulations will be violated or where a major problem in potability or treatment will occur other than some increase in costs and/or potential taste and odor complaints from consumers. Several issues such as the blending of new water supplies for both raw and finished water are too complex to be dealt with in detail at this level of effort. However, it appears that the consequences on potability of such blending will be minor. Certainly optimum management of the overall MWA water supply system is important to reducing any negative impacts to a minimum. To this end, close cooperation between MWA authorities in developing and implementing management strategies is essential. Additionally, using available computer systems to assist in the management along with the development of needed new computer systems is an important consideration particularly in the future as the supply problems become more critical.

Specific conclusions derived from the study are summarized as follows:

A. Comparison of Raw and Finished Water Quality

1. While the raw and finished waters showed overall differences in water quality, the differences are not strong enough to support a conclusion that the overall water qualities are significantly different.

2. Because of the weak differences in overall water quality of the raw and finished water quality, the impact of these differences on water supply decisions will be of a small order of magnitude.

B. Comparison of Plant Flexibility

1. While some plants are more flexible than others, all of the plants have adequate flexibility to compensate for anticipated quality changes in supply.

2. Currently planned renovations will bring the WSSC Patuxent and WAD McMillan plants to a flexibility level comparable to other plants within their respective authority.

C. Interconnections and Reregulation

1. Water quality of the Occoquan and Patuxent Reservoirs probably will not be greatly affected by reregulation beyond the ordinary variations of the supply or the ability of the treatment facilities to minimize change in finished quality.

2. A quantitative assessment of the effects of blending different waters in the distribution is complex and beyond the scope of this effort. However, no evidence was found that serious problems will occur. In addition, there appears to be adequate plant operational control flexibility to minimize potential negative effects of blending.

3. The less frequent and smaller the source changes are, the fewer the problems in water quality and potability.

4. Optimal management of the overall MWA water system will result in minimal source changes thus reducing to a minimum problems in water quality and potability.

5. Finished water interconnections have less potential for producing consumer complaints than does the procedure of reregulation.

6. Since the differences in finished water tend to be second order, effects of finished water interconnections should be of a minor nature.

7. The concentrations of phosphorous, inorganic nitrogen, and total alkalinity are generally higher in the Potomac River than in the Rocky Gorge and Occoquan Reservoirs.

8. Both reservoirs would experience an increase in total alkalinity concentrations as a result of the interconnections.

9. The Potomac River - Rocky Gorge Reservoir interconnection could cause increased entrophication in Rocky Gorge due to projected increases in nutrients, especially phosphorus.

10. Under the conditions of the hydrologic scenario, Occoquan Reservoir water quality would probably not be significantly impacted by the Potomac River - Occoquan interconnection.

11. Increases in alkalinity and nutrient availability resulting from input of piped Potomac River could cause increases in treatment costs at the filtration plants. These costs are related to more frequent filter backwashing and the need for greater quantities of coagulants.

12. Neither of the raw water interconnections are expected to cause violations of existing Federal, State, or local water quality standards.

13. The water quality effects of pumping reservoir water to the Potomac River are minimal.

14. Overall, the changes resulting from raw water interconnections should not be great enough to cause problems in treating except for potential increased algal production leading to higher costs and possibly increased taste and odor complaints.

15. The necessary information to determine the cost effectiveness of using Potomac estuary water will be provided by the Experimental Estuary Water Treatment Plant pilot study being conducted by James M. Montgomery, Consulting Engineers, Inc.

16. Because of the difficulty in determining potability on an absolute basis, there is always a potential for an undetermined health problem to be associated with a particular water study. The presence of treated sewage in the Potomac River estuary increases this potential.

17. Public acceptance or rejection of a drinking water which uses treated sewage in any proportion is a critical issue which needs to be evaluated. It may be necessary to develop strategies which will ameliorate acceptance or rejection problems.

BIBLIOGRAPHY

1. U.S. Environmental Protection Agency, Office of Water Supply, National Interim Primary Drinking Water Regulations, EPA-570/9-76-003 (1975).

2. U.S. Environmental Protection Agency, "National Secondary Drinking Water Regulations," Federal Register, 44:140, 42195-42202 (July 19, 1979).

3. Work Health Organization. European Standards for Drinking Water, Second Edition, Geneva (1970).

4. "Public Health Service - Drinking Water Standards," Publication No. 956, Revised 1962; U.S. Department of Health, Education, and Welfare; Public Health Service, Washington, DC (1966).

5. "Report of the Committee on Water Quality Criteria," Federal Water Pollution Control Administration, Washington, DC (April 1, 1968).

6. Gardels, M. D. and Schock, M. R., "Corrosion Indices: Invalid or Invaluable?" Drinking Water Research Division, Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, OH.

7. Patterson, J. W., "Corrosion in Water Distribution Systems." Office of Drinking Water, U.S. Environmental Protection Agency, Washington, DC (March 1981).

8. Ainsworth, R. G., Oliphant, R. and Ridgeway, J., "The Introduction of New Water Supplies into Old Distribution Systems," Technical Report TR 146, Water Research Centre, Oxford (September 1980).

9. "Metropolitan Washington Area Water Supply Study: The Effects of Raw Water Interconnections on Water Quality," Prepared for Baltimore Corps of Engineers by EnviroPlan, Incorporated, Springfield, VA (December 8, 1978).

10. Clark, R. M., et al., "Analysis of the Economics of the Water Supply in the Washington Metropolitan Area," EPA Report EPA-600-12-80-136, Drinking Water Research Division, Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, OH (July 1980).

11. Metzler, D. F., Culp, R. L., et al., "Emergency Use of Reclaimed Water for Potable Supply At Chanute, Kan.," Jour AWWA, 50:1023 (August 1958).

12. Sheer, D. P. and Harris, D. C., "Acidity Control in the North Branch Potomac," Jour WPCF, Vol. 54, No. 11 (November 1982).

13. "Project Development Report on Little Seneca Lake for the Washington Suburban Sanitary Commission," Contract No. 76BD2823.C, Black and Veach Project No. 8452 (1980).


F